ASTRONOMY

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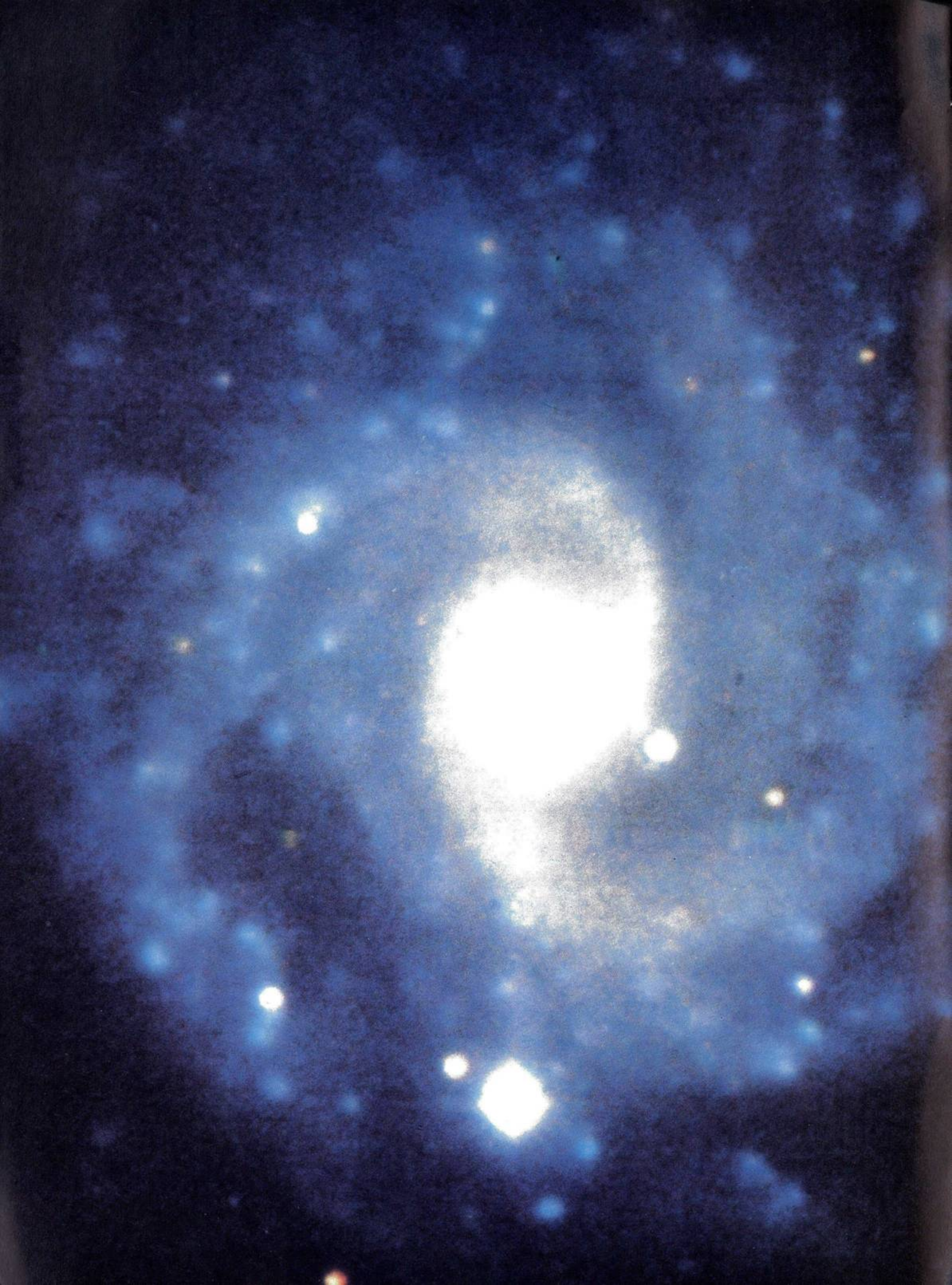

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Cover: For all their apparent beauty, spiral galaxies remain as inscrutable as ever. But astronomers believe they are at least closer to understanding the forces that shape the spiral arms, like those in the open spiral NGC-2997. Anglo-Australian Observatory photograph. These pages: A charge-coupled device image of NGC-3184 reveals this galaxy's classic spiral form. Smithsonian Astrophysical Observatory photograph.

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How Do Spiral Galaxies Spiral?

by Neil Comins and Laurence Marschall

"Form is a diagram of forces."
D'arcy Wentworth Thompson,
On Growth and Form (1917)

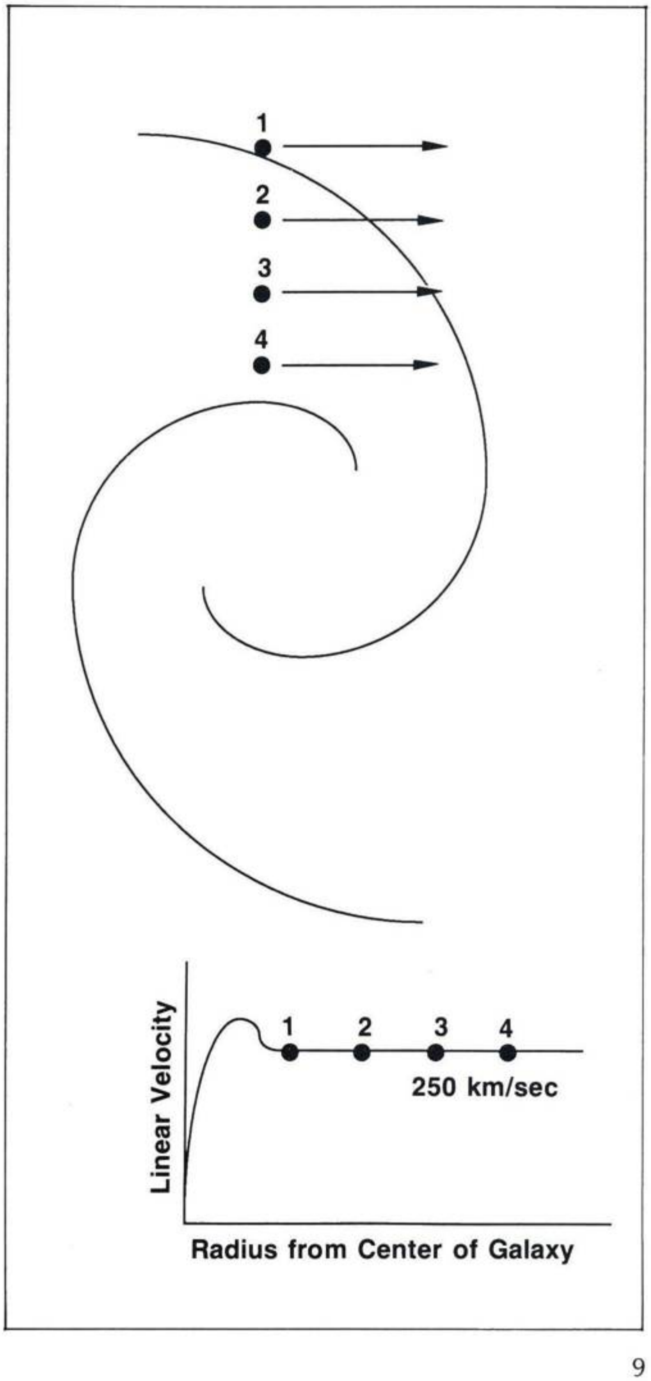
From the very small to the incredibly large, there are countless examples of objects in our universe with shapes determined by natural forces. The shapes of snowflakes, for example, reflect the geometric structure of electric forces exerted between atoms in water molecules. The delicate filigree we see at the edges of sunspots and the arcs of gigantic loop prominences on the Sun trace the patterns of solar magnetic field lines. Globular clusters, as well as individual stars and planets, owe their impressive spherical symmetry to gravity's relentless inward pull.

Yet force cannot always be readily deduced from form. The shapes of spiral galaxies, which rank among nature's most striking forms, resist straightforward interpretation, despite over four decades of research. Scattered throughout the universe, these large congregations of stars, dust, and gas display extravagant shapes that seem to owe as much to the life histories of the individual stars and interstellar gas within spiral galaxies as to any single molding force. Recent theoretical work, much of it done on large supercomputers, coupled with new observations of the internal structure and motion of spiral galaxies, are bringing us closer to an understanding of the complex nature of spiral galaxies. But these theories and observations are also causing us to set aside many once-cherished notions about how galaxies form and evolve.

Patchy areas of bright blue stars trace out the loose spiral arms of M-101, an Sc-type spiral in Ursa Major. Photo by James D. Wray, McDonald Observatory.

Complex Spiral Structure

Some spiral galaxies, such as NGC-3992 in Ursa Major, have complex structures like spiral arms and bars. Spiral density-wave and stochastic star formation theories must address the forces shaping these galaxies as well as "normal" spiral galaxies. Photo courtesy Smithsonian Astrophysical Observatory.



The Rotation of Stars in Spiral Galaxies

Stars orbit the center of most spiral galaxies at nearly the same linear velocity, no matter how distant the stars are from the center (top). A plot of the linear orbital velocities of stars at various distances from the center results in a flat rotation curve (bottom).

Understanding 'Spiral Nebulae'

Although fuzzy patches of light, called nebulae, have long been known to astronomers, William Parsons, Lord Rosse, using a 72-inch telescope in the mid-1800s, was the first to recognize that some nebulae were spiral shaped. Astronomers back then speculated that the nebulae could be far-flung star systems like our own Milky Way Galaxy (in fact, Immanuel Kant first made such a proposal in the mid-1700s), but the preponderance of scientific opinion rejected this hypothesis. Not knowing the distances to these objects (much less the distances to the stars), astronomers of that period could only speculate about the true nature of these pinwheels of light.

During the opening decades of the twentieth century Harlow Shapley established the dimensions of our Galaxy from the relationship of the period and apparent brightness of Cepheid variable stars in globular clusters. Shapley showed that instead of being a star system a few thousand light-years in diameter, the Milky Way was a vast, flattened disk of some 100 billion stars about 100,000 light-years in diameter surrounded by a thin, spherical halo of globular clusters. This discovery changed astronomers' perceptions of distance in the universe and stimulated debate over whether spiral nebulae were galactic or extragalactic objects.

The issue was finally resolved in 1923 when Edwin Hubble identified Cepheid variables in the Andromeda Galaxy. Applying the same period-luminosity law Shapley had used, Hubble determined that the Andromeda Galaxy lay far beyond the Milky Way. Other spiral nebulae, astronomers soon realized, lay even farther out, at distances into the billions of light-years. Astronomers had to admit the universe extended to unimaginable distances and that a multitude of galaxies — huge star systems each containing hundreds of billions of stars — was scattered throughout the universe.

Judging a Spiral by Its Shape

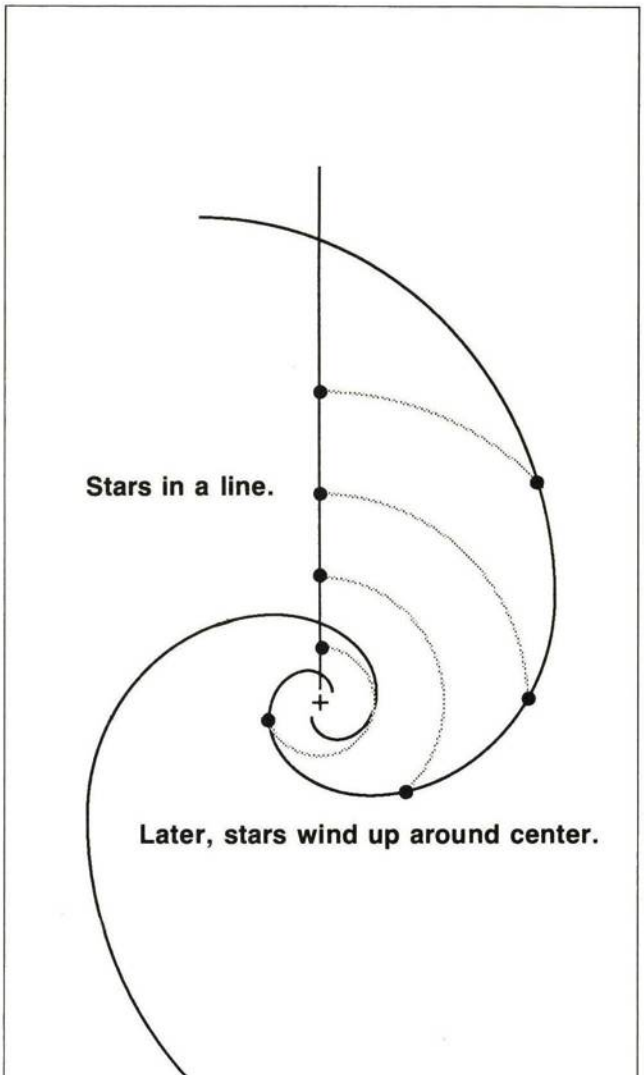
With the extragalactic nature of galaxies established, Hubble went on to categorize galaxies based on their forms. He recognized several different types — some ellipsoidal in form, others ragged and irregular — but over a third of the galaxies he cataloged were classified as spiral (denoted by "S" in Hubble's classification scheme). The Pinwheel Galaxy, M-101 in Ursa Major, is a particularly striking example of the galaxies Hubble classed as spirals. Evident in photographs is a central spherical bulge

A Grand Design

With its distinct, continuous spiral arms and overall symmetry, NGC-2903 in Leo represents an example of a grand design galaxy shaped by a spiral density wave. Photo by James D. Wray, McDonald Observatory.

The Winding Dilemma

Stars closer to the center of a spiral galaxy don't have as far to go to complete an orbit as stars located farther from the center. Thus, inner stars should orbit more frequently than outer stars, resulting in a spiral that gradually winds up as the galaxy ages. But observations of spiral galaxies at various distances — and thus at different stages in their evolution — have shown this is not the case. Astronomers believe density waves, stochastic star formation, or perhaps a combination of both processes may sustain or regenerate the spiral pattern.



from which wispy arms emerge, extending out to distances 100,000 light-years from the center of the galaxy.

Appearances can be misleading though. What we see in photographs are only the most luminous objects in the galaxy: bright blue stars — the youngest and brightest types of stars — and large clouds of gas illuminated by the blue stars trace out the arms in M-101 and similar spirals. Many dark, cool clouds of gas and dust along with many redder, fainter stars between the spiral arms escape our immediate attention because these clouds and stars don't show up as readily in photographs taken in blue light.

When all the dark interarm mass is taken into account, the spiral appearance of galaxies seems more like a decorative feature than an essential structural aspect of galaxies. Astronomers understand spiral arms as regions of enhanced light output embedded in a broad, flattened disk that surrounds the central bulge of the galaxy.

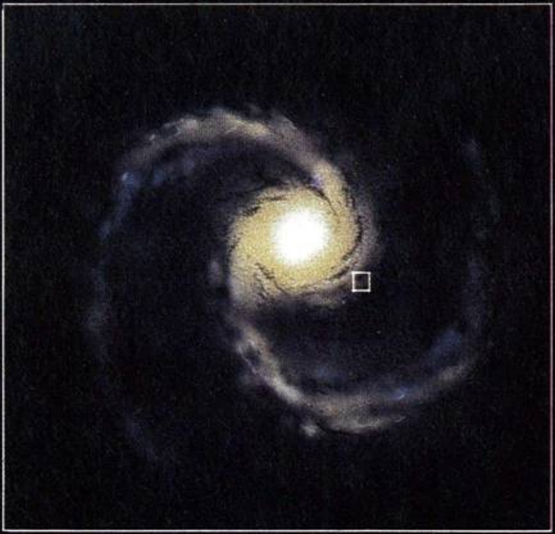
But even the material visible in the disk may be just the tip of the galactic iceberg. Surrounding the optical disk of the galaxy is a halo of faint globular clusters and, many astronomers believe, an extensive corona of nonluminous material. This nonluminous material has a gravitational force essential to hold the galaxy together, but its exact nature is still unknown.

When a spiral is viewed from the side, as is M-104, the Sombrero Galaxy, the disklike appearance of the spiral arms is emphasized. Globular clusters are too faint to be seen around most spirals, though globular clusters have been detected around nearby galaxies such as M-31.

Trying to make sense of the various patterns of spiral galaxies leads us into a thicket of difficulties. As Hubble himself recognized, the central regions of spirals seem to fall into two groups: those with spherical bulges (normal spirals) and those with a bar of bright stars running through the center (barred spirals). Both normal and barred spiral galaxies show further marked variation in how prominent the central bulge is and how tightly wound the spiral arms appear. Hubble classified normal spirals that display a large central bulge and tightly wound arms as type Sa galaxies. Spirals that have a less distinct bulge and more extensive arms were designated type Sb. Galaxies with inconspicuous nuclear regions and loosely coiled spiral arms were designated type Sc.

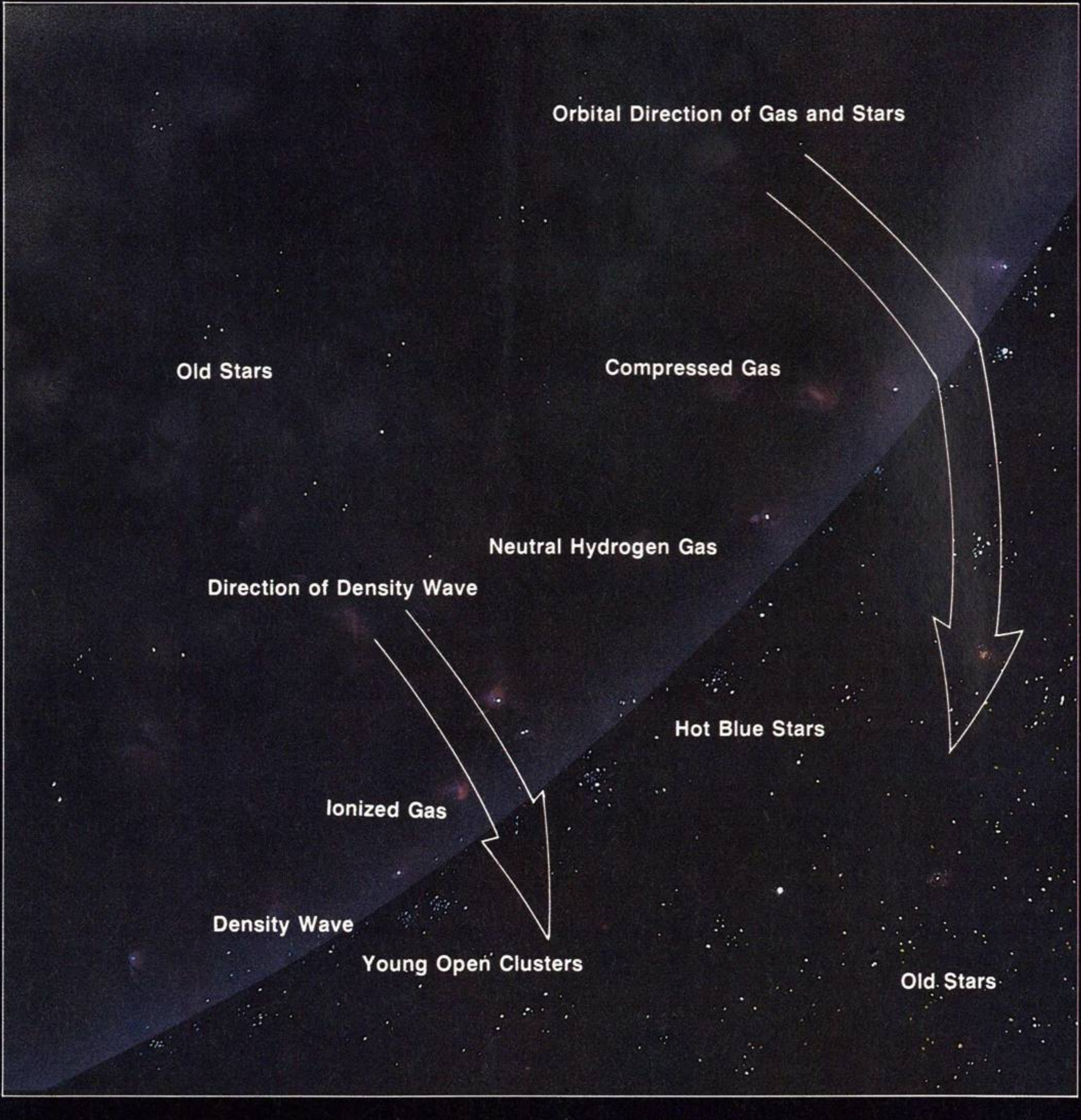
In recent years astronomers have drawn attention to another notable distinction. Some spirals display sharply defined arms winding out symmetrically on opposite sides

Two Spiral-Shaping Forces



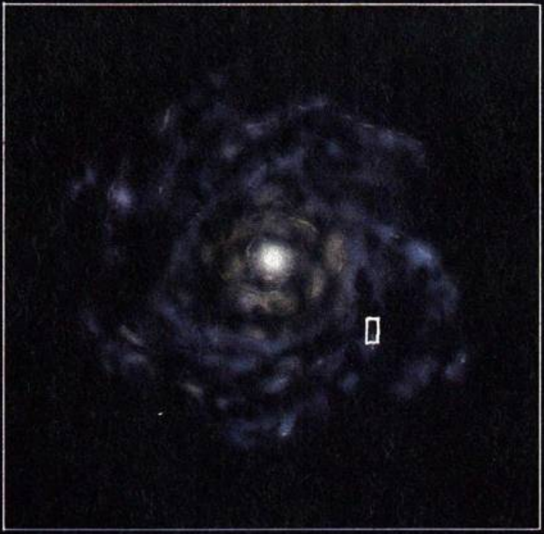
Density Wave

Like a wave rippling across a quiet pond, a density wave moves around the center of the galaxy, though only half as fast as the rotational velocity of the stars. The increased density caused by the bunching together of stars and gas in the wave attracts and pulls in other nearby gas, forcing the gas out of a circular orbit. This change of direction shocks and compresses the gas so it ultimately collapses and forms new clusters of hot, blue stars.


Orbital Direction of Gas and Stars
Old Stars
Compressed Gas
Neutral Hydrogen Gas
Direction of Density Wave
Hot Blue Stars
Ionized Gas
Density Wave
Young Open Clusters
Old Stars

Stochastic Star Formation

Expanding clouds of debris from supernova explosions plow up surrounding gas, causing it to collapse into stars, The more massive stars will also form into supernovae in a few tens of millions of years, continuing the cycle. Galaxies in which this kind of chain-reaction star formation occurs display a mottled disk rather than a uniform spiral pattern.



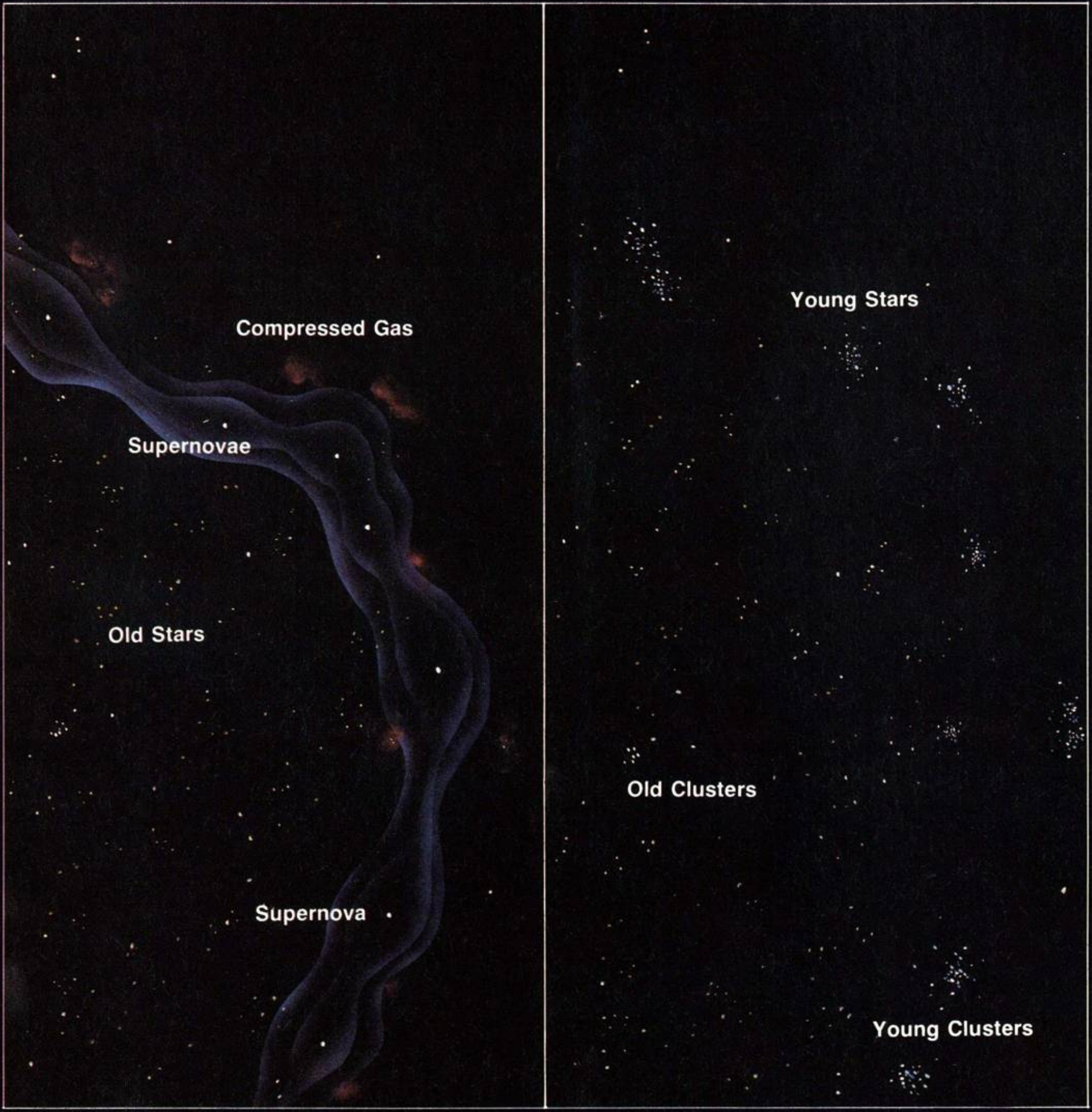

Compressed Gas
Supernovae
Old Stars
Supernova
Young Stars
Old Clusters
Young Clusters

Illustration by Tom Hunt

The Patchy Flocculent Spiral

The fragmentary spiral structure and generally patchy appearance of the disk are the earmarks of a flocculent spiral galaxy shaped by the stochastic process. Photo of NGC-5055 by Rudolph Schild, Smithsonian Astrophysical Observatory.

of the center, while others show more chaotic structure — many loosely defined arms, fragments of spiral arms beginning far from the center and ending abruptly, wisps bridging adjacent arms, and a generally patchy appearance. The symmetrically shaped spirals are called "grand design" galaxies; the others are labeled "chaotic" or "flocculent" galaxies.

Why such striking differences in form? Could a single force be responsible for the various shapes observed in spiral galaxies, or a conspiracy of forces? Surely a clue to the shapes of spiral galaxies must lie in the motions of the stars that make up spiral galaxies. Just as the planets of the solar system cannot remain motionless in space but must orbit around the Sun, so the stars in a galaxy must move under the influence of gravitational forces. But the stars' motions are more complex. Unlike the solar system, where the Sun's gravity is the dominant force, a star's direction is influenced by the gravitational force of all the other moving stars and gas around the star. In general, though, all stars orbit the galactic center. Our Sun, for instance, lying about three fifths of the way out from the center of the Milky Way, completes one orbit every 250 million years.

The Winding Dilemma

When we consider motions of stars about the centers of spiral galaxies, we encounter a serious problem. We see spiral galaxies frozen in time, each looking like an enormous pinwheel. The orbital motions of the stars seem obvious: Stars near the bright core must orbit at higher speeds than those stars residing farther out, in a fashion corresponding to Keplerian planetary law.

But the stars near the core don't orbit faster. Observations by astronomers Kent Ford, Vera Rubin, Morton Roberts, and others over the past three decades have shown that rather than dropping off, the linear rotation speeds of stars in spiral arms do not vary much from the center to the fringes. Most astronomers have long assumed that the area of greatest mass in a spiral galaxy is also the area of greatest luminosity — the center. But the velocity curves — graphs showing the linear orbital velocity of stars at increasing distances from the center — have proved that assumption incorrect.

The best explanation for the high orbital velocities of fringe stars is that spiral galaxies are embedded in spherical haloes of dark matter that extend well beyond the galaxies' visible disks. The gravitational attraction of this hidden mass pulls on the stars as they make their way around the galaxy and makes even the outermost stars orbit at high velocities.

The fact that the orbital velocities of stars remain nearly constant, even as distance from the center increases, means it is impossible for the bright arms to rotate as rigid systems. Imagine that the stars in a spiral arm are initially assembled together along a line pointing directly away from the center. The stars closer to the center move around the nucleus sooner than those stars located farther out. For a while the straight line bends into a pattern just like a typical spiral arm, but within a few rotations the line winds up from the inside out like a watch spring. Therefore we can predict that if a galaxy begins as a type Sc, it will in time change to an Sb and then an Sa.

Is there any evidence for such winding? If the youngest spirals were Sc and the oldest Sa, we might believe the winding process was the main cause of spiral structures. But how can we determine the age of a spiral galaxy? The simplest way is to look at galaxies lying at great distances. The farther a galaxy is from us, the longer its light has traveled to reach our telescope, so the farther into the past we are seeing. Assuming all the galaxies were created at roughly the same time, a more distant galaxy should appear younger; and if all galaxies wind up as they age, the more distant galaxy should also resemble an "unwound" Sc type.

Yet astronomers find essentially the same number of Sa, Sb, and Sc galaxies at all distances from us. There is no systematic difference in spiral structure with distance; therefore Sa, Sb, and Sc galaxies have roughly the same ages. This strongly suggests spiral galaxies are *not* winding up.

What's wrong here? How can stars have different orbital periods — as we observe — and also trace out spiral patterns — as we also observe — yet still not wind up over periods of billions of years?

Something must sustain a spiral pattern, keeping stars from going their separate ways. Either the spiral patterns we see are somehow *preserved* as the stars orbit through them, or they are constantly *regenerated* with new arms forming as old arms disappear.

Astronomers have come up with two competing ideas to resolve this "winding dilemma." First and oldest is the spiral density-wave theory, which proposes a way in which the patterns can be preserved intact. Second and

The M-81 Exception

The classic spiral shape of M-81 in Ursa Major represents a contradiction of forces. In other spiral galaxies the linear orbital velocities of stars have been shown not to decrease with distance from the center. But recent observations indicate that the velocities of stars on one side of M-81 *decrease* with distance from the center, while those on the opposite side do not. The difference may be due to the gravitational influence of the nearby galaxy M-82. California Institute of Technology photograph.

more radical goes by the name stochastic self-propagating star formation, which proposes that the spirals are constantly regenerated.

Density Waves Form Spiral Arms

Matter in spiral galaxies is typically distributed partly as stars and partly as interstellar gas and dust. In the late 1950s and early 1960s the Swedish astronomer Bertil Lindblad proposed that regular bunching in the stars as they move through the galaxies, a sort of stellar traffic jam, could account for the spiral patterns we see. An increased star density of as little as 5 percent could ripple through an entire galaxy like a wave across a quiet pond, taking on a spiral shape caused by the different orbital motions of the stars. In 1964 Chia Chiao Lin from the Massachusetts Institute of Technology and Frank Shu of the University of California elaborated on the spiral density-wave theory, showing how overall spiral structure could occur without winding up and disappearing.

To begin with, the theory states, a galaxy is formed without spiral arms. A later disturbance, perhaps the gravitational nudge of a passing galaxy, triggers the formation of a density wave, which typically assumes the form of a simple, two-armed spiral.

Entering the wave, orbiting stars and gas crowd together. As a result of the increased density of material there, the wave has greater gravity than surrounding parts of the galactic disk and pulls nearby gas out of a nearly circular orbit and into the arm. Where the direction of gas flow changes, it is also compressed, forming a "shock," the same phenomenon, on a far grander scale, as the sonic booms created by high-speed aircraft. This shocked, compressed gas can cool, collapse, and form new clusters of main sequence stars.

Among the newly formed stars a small fraction will be much more massive than the Sun (from three to fifty times as massive.) These massive stars — by far the brightest of all stars in a galaxy — form along the spiral arms and embroider the density wave with light, creating the impression that most of the spiral galaxy's mass lies in the arm. Most of the mass isn't really there, however, for the arms are only a few percent more concentrated than average.

Just as a water molecule in the ocean moves at a different speed from the waves it passes through, stars and gas in spiral arms do not travel at the same speed as the spiral pattern. Typically the gas and stars move about twice the speed of the density wave: they catch up with the wave, enter it, and pass through it over a period of several million years. Consequently, shortly after new stars form, they move through and away from the spiral density wave, leaving room for further star formation through new gas entering the arm.

Does this imply that eventually the entire disk of a galaxy should be filled with brighter stars? Will we be faced with a new sort of "unwinding dilemma" as the newly formed stars gradually stream out of the arms into the surrounding disk? Not at all. The bright, massive stars that highlight the spiral arms shine only for about 10 million years, much less than the time needed for one orbit around the center of the galaxy. Therefore, shortly after they move away from their place of birth, they die, often as violent supernova explosions like the one discovered in February 1987 in the Large Magellanic Cloud. The remnants — white dwarfs and neutron stars — continue to orbit the galaxy, but they no longer shine with outstanding brilliance. The numerous remaining lower-mass stars in each cluster are much dimmer, and though they last longer, eventually moving out of the density wave, they don't contribute much to the overall light of the galaxy. As these stars exit the density wave, fresh gas enters at the opposite edge of the arm, forming new bright stars. Thus the spiral pattern is preserved.

Density Waves Aren't Forever

There are at least two major problems with the density-wave theory. First, in 1971 Alar Toomre of the Massachusetts Institute of Technology determined that density waves die out within a billion years or so unless they are somehow restimulated. If the stimulation required is the passage of another galaxy near the spiral, then spiral density-wave theory runs afoul of observation: we see plenty of isolated spiral galaxies that do not have companions to perturb the gas and renew the waves. On the other hand, if the stimulation comes from the explosions of supernovae, these explosions would have to be more frequent or more powerful than we believe them to be.

Density-wave theory also predicts that stars should form most noticeably along the trailing edge of the density wave, where gas entering the wave first becomes compressed. Observations in 1984 by Bruce and Debra Elmegreen of the IBM Thomas J. Watson Research Center in Yorktown Heights, New York, show that indeed some galaxies — the "grand design" galaxies we mentioned ear-

A Galaxy Wracked by Supernovae

The Sc-type spiral M-83 in Hydra is known for its high frequency of supernovae, which may partially explain the fragmentary spiral arms lying outside the two main arms. M-83 also displays a barlike structure that runs through its nucleus and is oftentimes classified as a transition between an open and a barred spiral. Anglo-Australian Observatory photograph.

lier — do have star formation localized at one edge of the spiral arms. But a large number of galaxies, the "flocculent" spirals, do not.

Supernova-Triggered Star Formation

The observations of flocculent galaxies are consistent, however, with a second, more radical mechanism for renewing the spiral arms: stochastic self-propagating star formation. The stochastic model was first formulated in 1978 by Humberto Gerola and Phillip Seiden of the IBM Thomas J. Watson Research Center, based on an idea proposed by Ivan Mueller of Ohio State University and David Arnett of the University of Chicago in 1976. Mueller and Arnett pointed out that even though supernova explosions usually affect only regions of the galaxy near the supernova by ejecting fast-moving clouds of debris, the effects eventually reach the overall structure of the galaxy. If there is enough gas surrounding a supernova, the supernova's expanding cloud of debris sweeps large amounts of compressed gas ahead of it like a snowplow and triggers further formation of stars. The more massive of these new stars in turn soon become supernovae, repeating the cycle until a relatively large region has been affected.

Randomly triggered star formation should thus produce lines of star clusters containing hot, young, blue stars. As a galaxy rotates, the lines of young stars are wound up into the spiral lanes we see as spiral arms. In time a spiral arm stretches and winds so much it disappears, but by then bright stars that once highlighted it have died away. Because enough random star formation is triggered continuously, new arms are always forming.

Stochastic star formation can be simulated by relatively straightforward computer programs. Theorists imagine a galaxy marked out by a gridwork of cells, each containing a certain number of stars and a certain amount of gas. The motion and changes in the state of matter in one cell affect the state of matter in the other nearby cells. A supernova at one position reverberates into the surrounding material in a way that can be calculated by the computer.

In the simplest models a supernova explosion in one cell induces adjacent cells to produce new stars at random. (Probabilities can be estimated by observing actual galaxies.) The method is similar to the way local weather conditions are used to predict the overall weather changes that occur on Earth. And just as the weather bureau can produce maps of changing cloud motion across the country, so astrophysicists can produce maps of impressive spiral structures, even motion pictures of how a galaxy's spiral arms should change with time.

As with the density-wave theory, however, there are several shortcomings to the theory of stochastic star formation. First, most computer simulations simply assume a certain probability that new stars form near supernovae but include relatively little consideration of real physical conditions and real physical processes. For instance, the programs assume interstellar gas is uniform over large regions of galaxies and responds to a supernova shock by forming a certain number of new stars. This is unrealistic because star clusters are known to form from giant molecular clouds that are irregular in shape and composition. A given supernova blast will affect different parts of the cloud differently.

Second, if star formation ignites further star formation, one should see clusters of increasing age strung like beads along the spiral arms of flocculent galaxies. Yet there is little evidence that the age of stars varies along the spiral arms, even in our own Milky Way Galaxy. One notable exception, however, is in the constellation Orion, where the youngest stars are found near the Great Nebula, older stars in the belt, and the oldest stars near Orion's head.

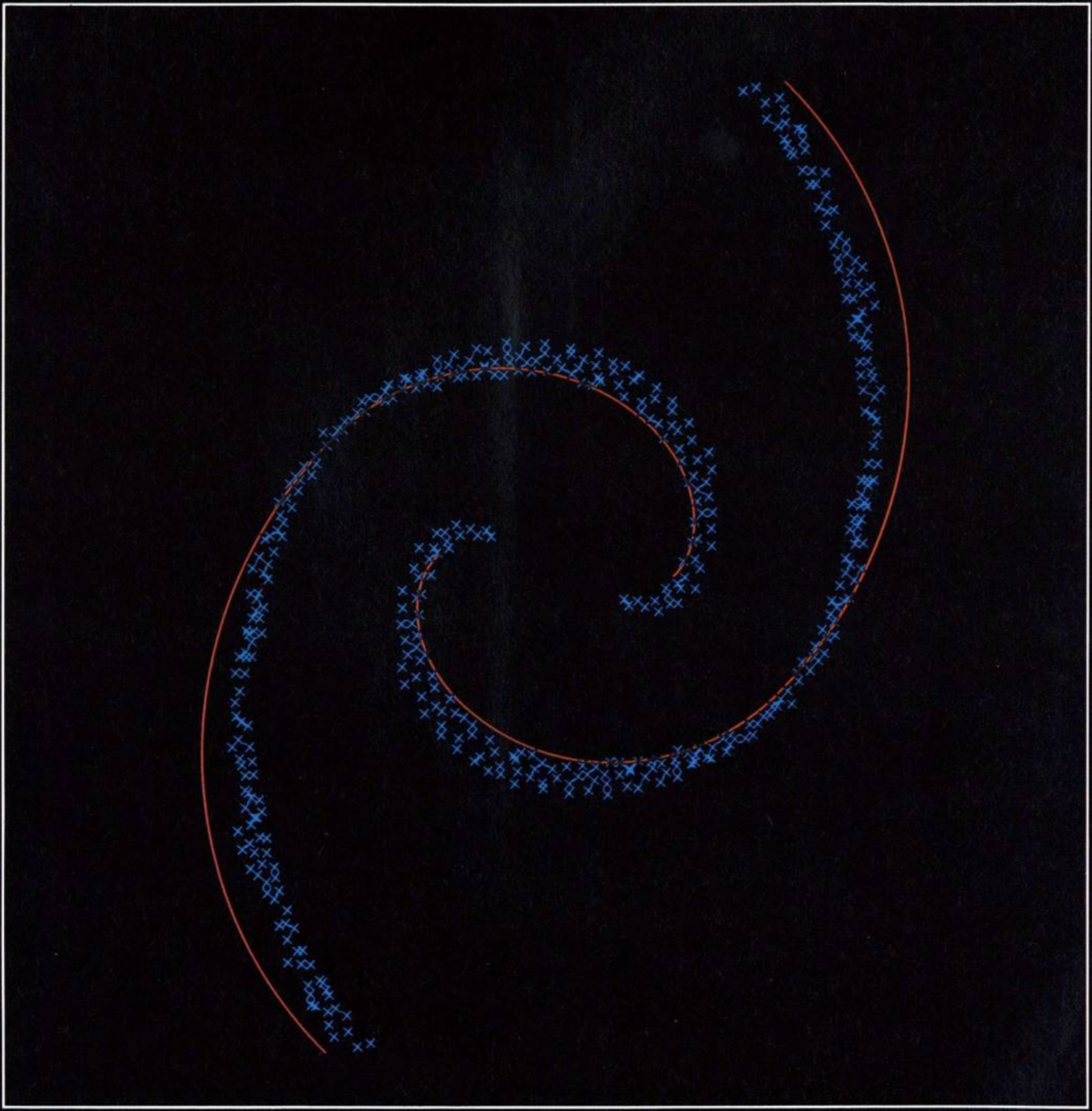
Current stochastic star formation programs also fail to reproduce reality because they usually assume that stars move in circular orbits around the galactic center; in reality stars orbit in ellipses. And until recent work by Balser and Comins in 1986, most computer programs did not even allow the material from supernova explosions to move from one cell of the theoretical grid to another or allow the blast to compress the gas nearby. This is a crucial point, for new star formation occurs in cells adjacent to supernovae because of the transfer of gas over large regions of space, not simply because of the pressure from the explosion.

The stochastic theory seems to involve a great many processes that are not yet fully understood. Why then has it generated so much interest? First, it produces realistic spiral structures under a wide variety of conditions. No matter what reasonable assumptions theoreticians make about the features of a galaxy — how probable star formation will be given in a cloud, how rapidly new stars are triggered by the deaths of old stars — the computers always produce credible spiral galaxies. Given the large number of such galaxies in the universe, this result is

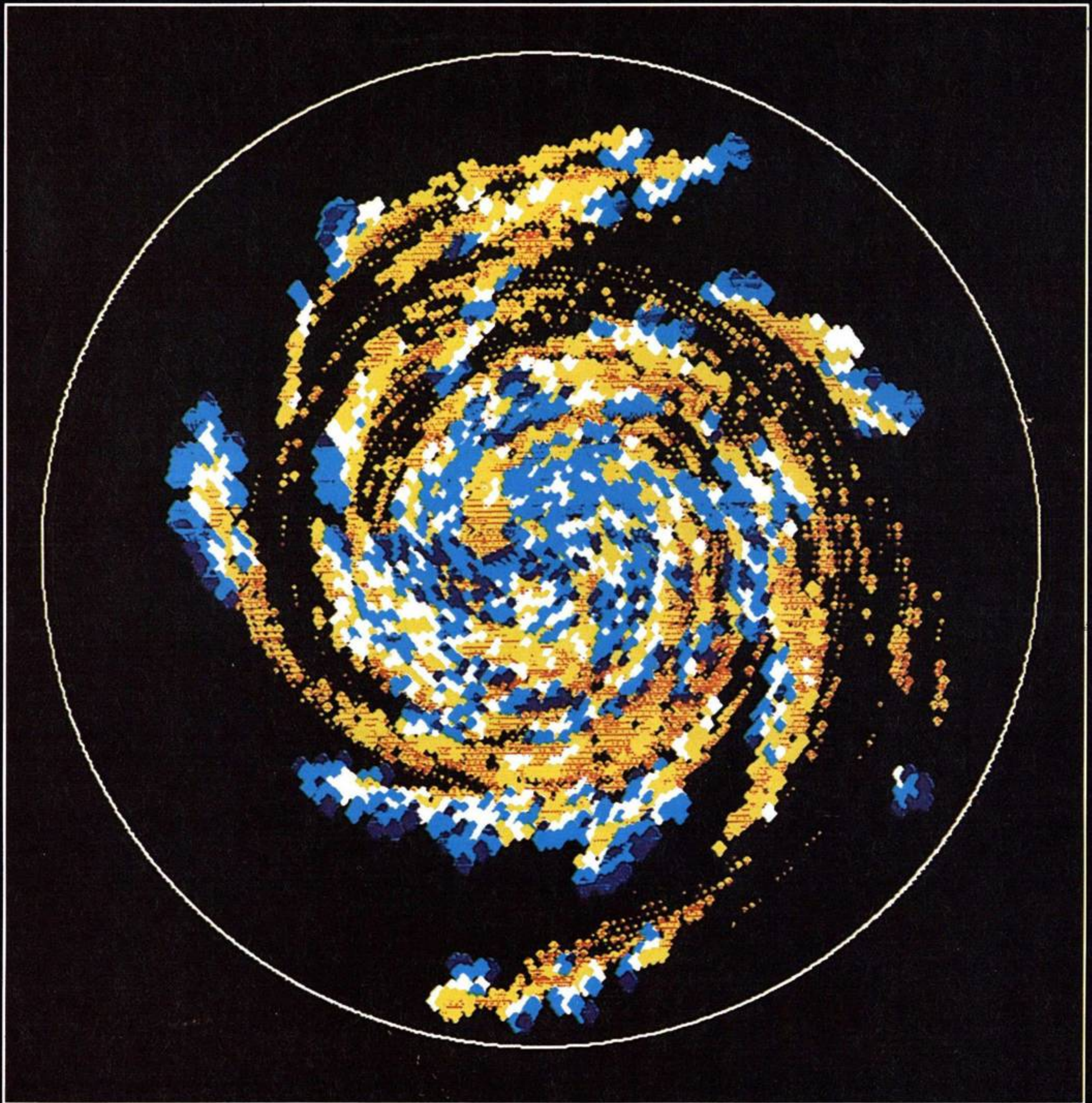
Computer-Modeling Looks at the Big Picture

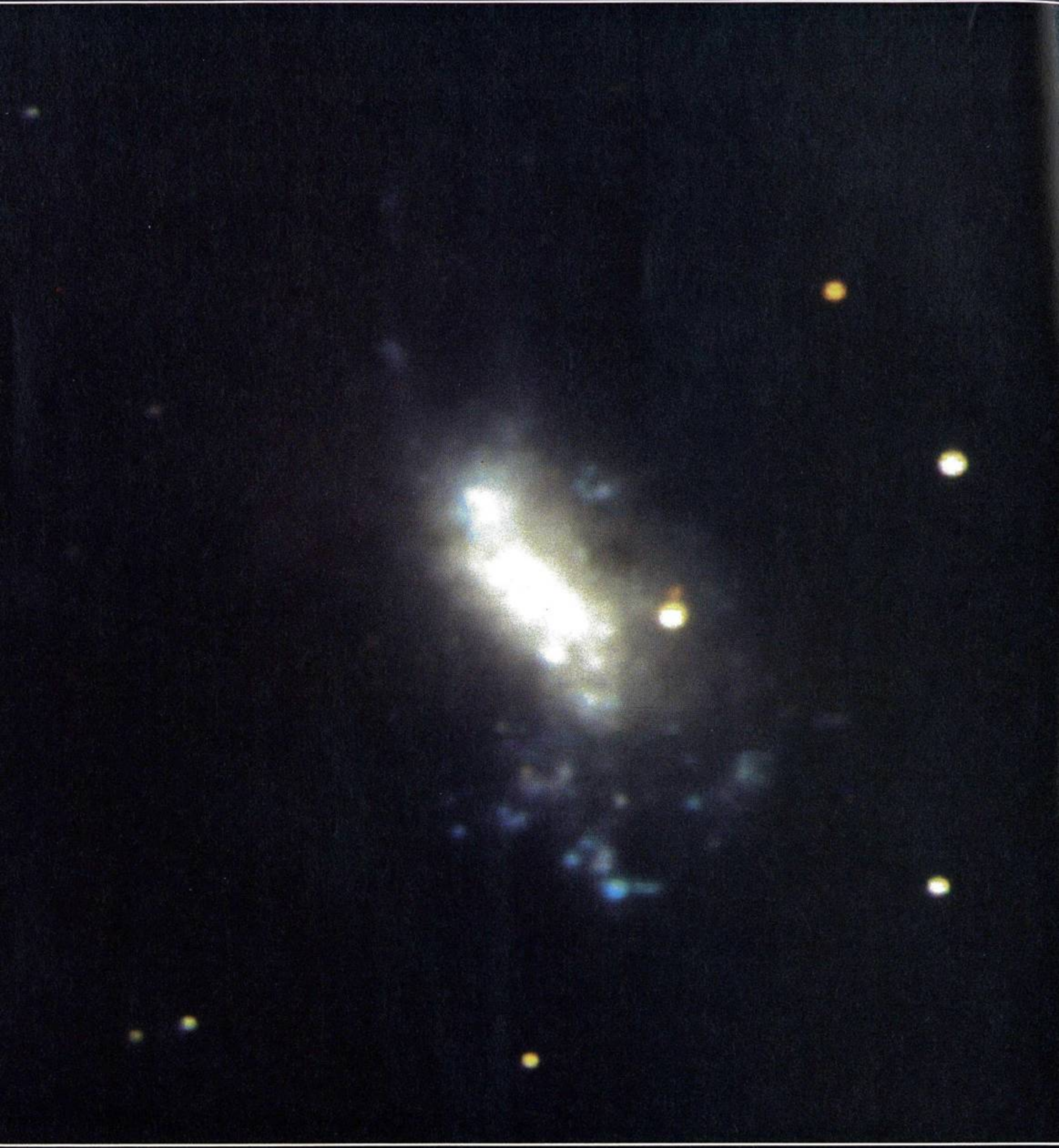
By applying many galaxy-shaping processes simultaneously, the computer advances our understanding of the forces that determine spiral structure.

Below: In this reoriented, face-on view of M-81 (compare with the photo on page 17), the most luminous, bluest stars (indicated by the blue Xs) and the crest of the density wave (indicated by the red line) were plotted by computer. Star density is greatest just behind the wave but becomes more diffuse once the stars pass through the wave. This illustration is based on a computer image generated by Frank Bash, University of Texas at Austin.



Below: Some computer models of stochastic self-propagating star formation produce realistic-looking spirals (compare with NGC-5055 on page 14). In this image young bright clusters are color-coded from violet to blue and old clusters from yellow to red. The symbol size is inversely proportional to the age of the star cluster represented. Note that young clusters are clumped in patches on both sides of the spiral arms. This illustration was produced by P. E. Seiden, IBM Thomas J. Watson Research Center, Yorktown Heights, New York.





Stochastic Process in an Irregular Galaxy

Stochastic star formation is not peculiar to spirals. The irregular galaxy NGC-4449 is believed to be forming stars by the stochastic process. Photo by Rudolph Schild, Smithsonian Astrophysical Observatory.

encouraging.

Second, astronomers see signs that even if the stochastic mechanism isn't responsible for all the features of all the flocculent galaxies, it most certainly accounts for some, such as the short chains of star clusters and the commonly seen interarm bridges.

New Computer-Modeling Needed

Both density-wave theorists and stochastic star formation theorists really only deal with a small part of spiral galaxy formation — the life cycles and motions of hot blue stars. Besides the hot stars that mark their arms, spiral galaxies contain countless faint stars with masses lower than that of the Sun, giant molecular clouds hundreds of light-years in diameter, magnetic fields, cosmic rays, and haloes of unseen matter. Perhaps we will eventually come to understand spiral structures by considering how all these elements interact.

But doing this efficiently requires sophisticated computer simulations that do not as yet exist. Such computer simulations represent a third and perhaps more promising approach to understanding spiral galaxy shapes. Ideally a meteorologist trying to understand hurricanes would construct a computer simulation of the entire atmosphere of Earth, including not just the motion of the atmosphere but its chemical and physical changes as well: the formation of clouds, the effects of pollution, the turbulence caused by mountains, and any other effect that could be modeled.

Despite the promise of this approach, the cost in computer time is immense. Only enormous programs running on the highest speed supercomputers may be able to include all the galaxy-shaping processes at the same time. Two types of programs show particular promise. One type, called an N-body model, considers a galaxy to be composed of a large number (as many as several hundred thousand) of interacting particles. The other type, called a hydrodynamic model, considers the material in a galaxy to be fluid, rather like the air. (Air, of course, also forms spiral patterns like cyclones but on a much smaller scale.) There are advantages to both programs. The N-body programs represent well the stellar component of a galaxy and can also be used to simulate the large, gravitationally bound gas clouds. The hydrodynamic codes address the distribution of more diffuse gas in galaxies as well as the entire galaxy in protogalactic collapse simulations. Astrophysicists in the United Kingdom, Canada, and the United States, among others, are attempting to combine the hydrodynamic and N-body approaches using existing supercomputers such as the Cray 1X/MP and Cray 2. Similar unified approaches may eventually prove successful in producing realistic-looking galaxies but, as in weather forecasting, complete success is slow in coming.

Both the N-body and the hydrodynamic models can already produce spiral patterns, but the spiral structure does not last. In most simulations, bars form at the center of the galaxy, which suggest barred spirals. By adding a massive spherical halo around the disk of the galaxy, computer simulations avoid the bar, but the mass required to do this far exceeds the amount of matter currently observed in galactic haloes.

To approach reality, future computer models must consider many other factors. Individual stars age in different ways — some spew out sizable amounts of gas during their lives, even if they do not become supernovae. Colliding stars can under certain conditions be ejected completely from the galaxy. Clouds of gas can collide with one another, which causes compression and star formation. Huge black holes, like that suspected near the center of the Milky Way, can drag in surrounding material and radiate prodigious amounts of energy. Passing galaxies can distort the shape of another — as our own Galaxy is distorted by the nearby Magellanic Clouds. Material can fall into a galaxy from such neighboring objects and even from the thin material between the galaxies. The list of effects that must be considered grows as we continue to observe galaxies with larger and more sensitive instruments.

It sometimes seems that understanding the splendid symmetry of spiral galaxies requires an understanding of all the unsolved problems of astrophysics. Perhaps that's true. Yet as computer power grows and our knowledge of the physics of the universe becomes deeper, the mystery will surely lift, and we may at last understand the complex mechanisms of growth and form that have produced these celestial wonders.

Neil Comins is assistant professor in physics and astronomy at the University of Maine and specializes in three-dimensional galactic modeling. Laurence Marschall is a professor in astronomy at Gettysburg College and is currently a visiting professor at Boston University. Marschall's specialty is the dynamics of young star clusters.

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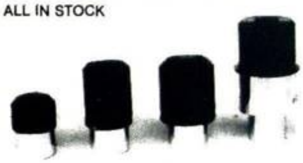

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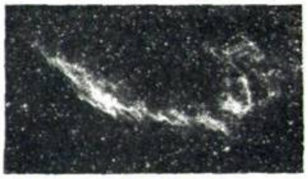

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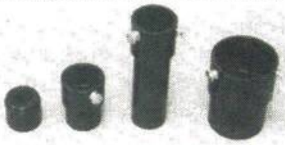

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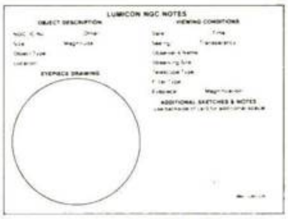
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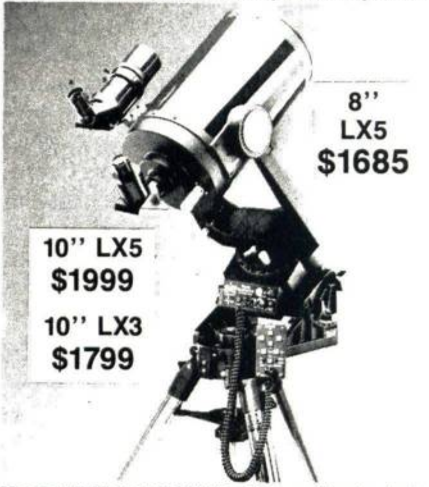

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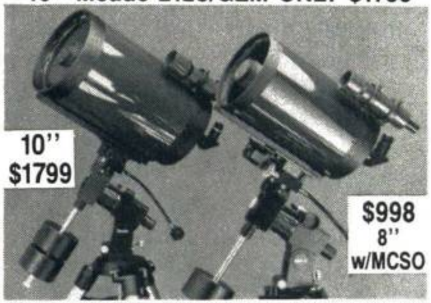

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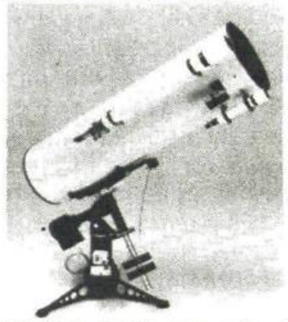

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Something Passing in

Interstellar space may be populated by mysterious cloudlike structures more numerous than stars.

Early in 1981 radio astronomers monitored quasar 0954+658 as it brightened slowly for a week. Then it abruptly faded to half its original intensity and remained that way for about two months. Suddenly the quasar's brightness soared again before finally dropping back to normal. But in the same period at a higher radio frequency the quasar's brightness dramatically rose and fell four times.

Something was obviously wrong with the measurements. The group of astronomers monitoring the quasar threw out this data.

For seven years this data lay unused until Ralph Fiedler, a postdoctorate astronomer from the University of Iowa hired to make sense of an entire set of quasar observations, noticed the data was missing. He retrieved the rejected data and fit it back together with the other observations. Only then did he realize that the quasar's unusual behavior pointed to a startling astronomical object — one that drifted in front of the quasar and caused the unique brightness variations.

A group of astronomers at the Naval Research Laboratory (NRL) had been gathering quasar observations as part of a long-range collaborative program with the U.S. Naval Observatory (USNO) since 1978. The Time Service of the USNO wanted to use the quasar observations to supplement the optical timing of stellar transits and other techniques for measuring time; the NRL was interested in tracking quasar variability.

Five times a day an array of radio telescopes at the National Radio Astronomy Observatory at Green Bank, West Virginia, monitored the radio emissions of sixteen quasars at two frequencies. In their study of quasar variability the NRL astronomers had examined small segments of the data; however, no one had analyzed all the data segments as a whole.

The First Step: Observations

Quasars — short for quasi-stellar radio sources — are extremely luminous objects located billions of light years from Earth. In optical telescopes they usually appear pointlike, just like stars. A small fraction of all quasars also emit radio radiation. Most of these quasars have very small angular diameters at radio frequencies, some only a fraction of a thousandth of a second of arc.

As early as the mid-1960s astronomers knew quasars vary in intensity. Some of this variability is caused by events in the nucleus of the quasar, presumably explosions that eject vast quantities of matter into space. Another reason for a quasar's apparent variability is scintillation. Irregularities in the ionized interstellar matter between the quasar and Earth cause these rapid and irregular variations in a quasar's brightness. (This is similar to the phenomenon that causes stars to twinkle as their light passes through Earth's atmosphere.)

The USNO and NRL planned to share the data collected by the Green Bank interferometer, which consists of two 85-foot telescopes in Green Bank, a 45-foot telescope some twenty miles away, and a 46-foot telescope approximately twenty miles distant and at right angles to the other three. (See "Two Telescopes Are Better than One" on page 29.) The scientists from the USNO would use the phase information; they didn't care how bright the source was, as long as they could see it. The NRL astronomers would use the amplitude information to learn more about the intrinsic variability of the quasars and the effect of interstellar scintillation, and a second here or there didn't concern them too much.

Observing the quasars at two frequencies — 8085 and 2695 megahertz (MHz) in this case — was particularly important to the NRL astronomers. Comparing the two signals can help distinguish between intrinsic variability and scintillation. Intrinsic variability shows up initially at the higher frequency and months later at the lower frequency. Scintillation, on the other hand, causes variations with a period of ten to eighty days and is more pronounced at lower frequencies.

One copy of the data tapes went to the Earth's Orientation Parameters Division of the Time Service of the USNO. From this copy David Florkowski, Demetrios Matsakis, and their colleagues obtained the phase information. This was then passed to the official keepers of the clock, who combined the quasar data with satellite observations, lunar ranging measurements, and star transits to set time.

The NRL group took its copy of the data tapes and examined the source brightness information in three-month intervals. Several postdoctorate researchers worked on the project under the guidance of Ken Johnston, the project's founder, but they always looked at small segments of the data. No one examined all the data until Ralph Fiedler arrived in October 1985.

Fiedler began the task of making sense of seven years worth of information by assembling the observations that

the Night

by Gerrit L. Verschuur

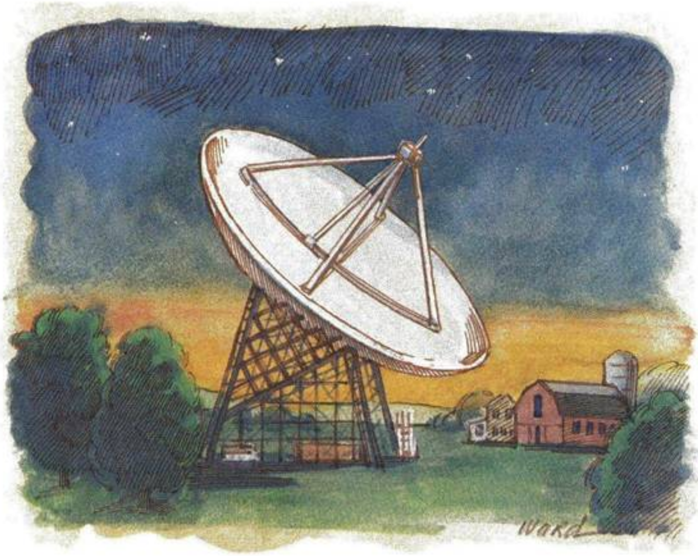
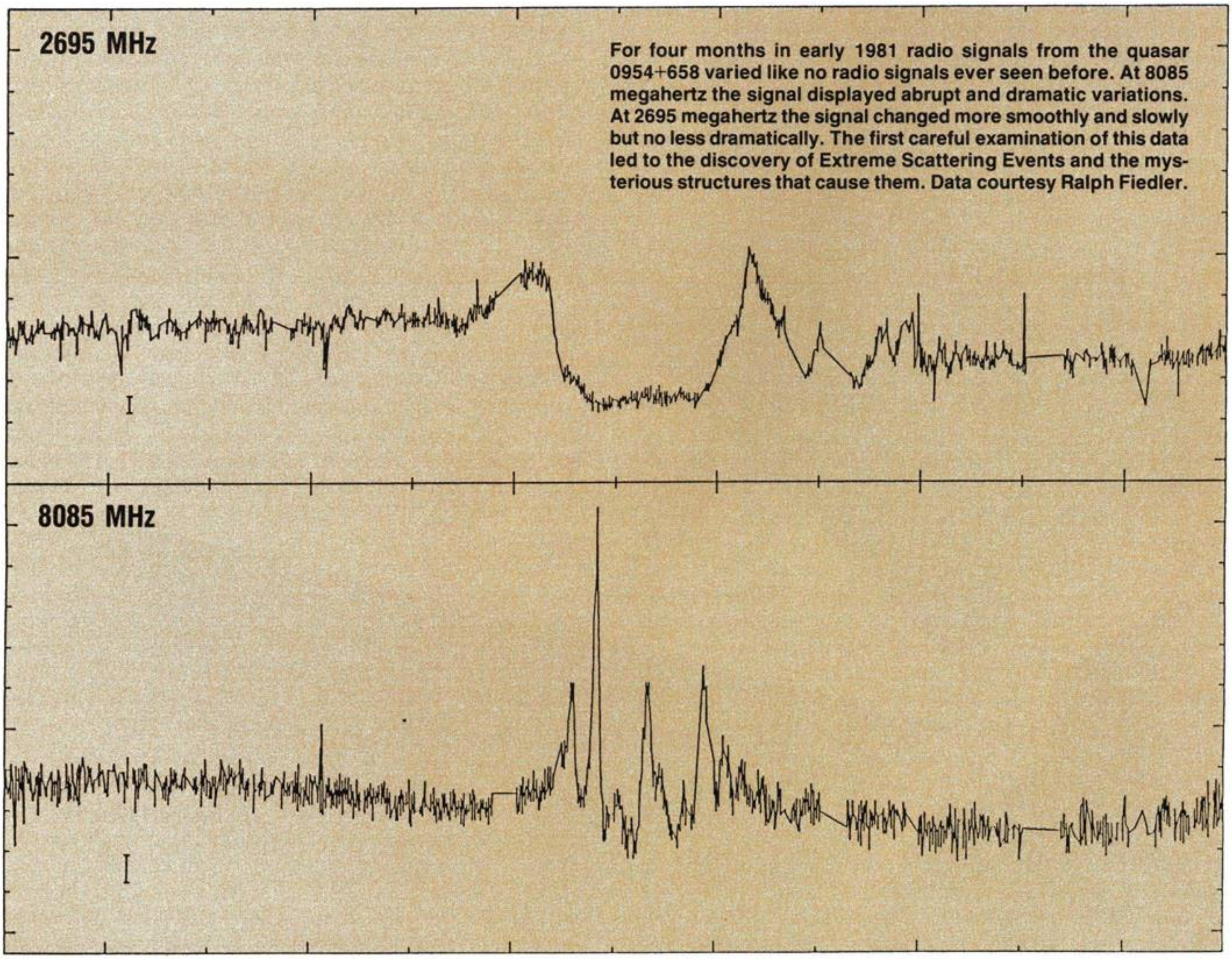


Illustration by Keith Ward

showed the strength of all sixteen quasars. Then he lined the walls of a corridor at the NRL's E. O. Hulburt Center for Space Research with this computer output and leaned back in a chair to get an overview of all the data.

Right away Fiedler noticed a subtle problem. Although the intensities of fifteen of the sources had been calibrated with respect to the quasar 3C 286 — chosen as a standard because the astronomers believed its output to be rock steady — the charts showed the brightness of all the sources changing together. Even though these changes amounted to only a few percent, they were a clear sign that systematic problems were affecting the analysis.

As he considered what to do next, Fiedler spotted a glaring four-month gap in the record of quasar 0954+658. He asked around and learned that previous researchers threw out that data because the source had exhibited such



For four months in early 1981 radio signals from the quasar 0954+658 varied like no radio signals ever seen before. At 8085 megahertz the signal displayed abrupt and dramatic variations. At 2695 megahertz the signal changed more smoothly and slowly but no less dramatically. The first careful examination of this data led to the discovery of Extreme Scattering Events and the mysterious structures that cause them. Data courtesy Ralph Fiedler.

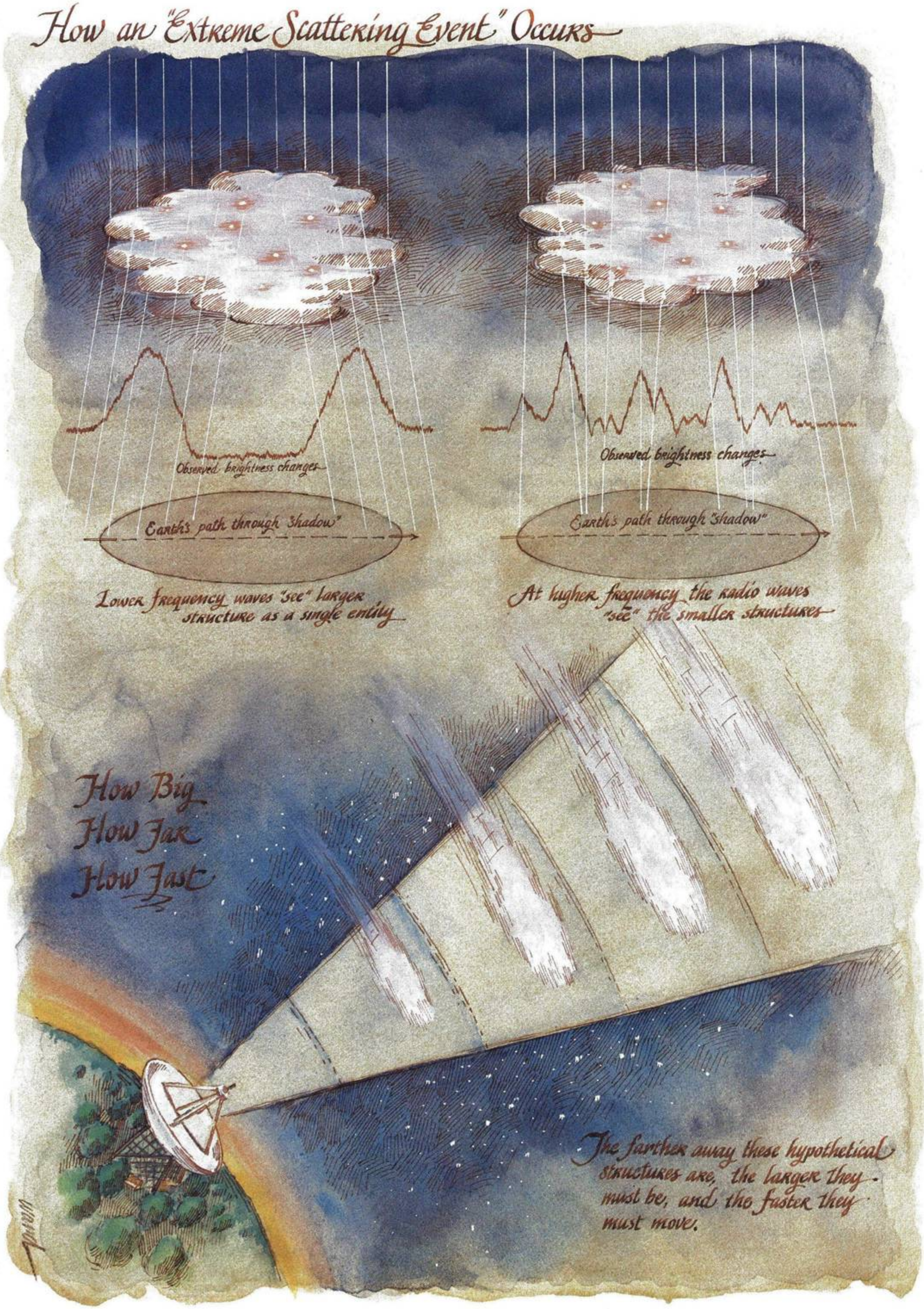

How an "Extreme Scattering Event" Occurs
Observed brightness changes
Earth's path through "shadow"
Observed brightness changes
Earth's path through "shadow"
Lower frequency waves "see" larger structure as a single entity
At higher frequency the radio waves "see" the smaller structures
How Big
How Far
How Fast
The farther away these hypothetical structures are, the larger they must be, and the faster they must move.

Diagram by Keith Ward

Two Telescopes Are Better than One

When two radio telescopes simultaneously observe a distant radio source, the resolution of the system is the same as that of a single antenna with a diameter equal to the separation between the telescopes. This technique, called radio interferometry, allows astronomers to see the radio universe in as much detail as they see the optical universe.

The radio waves arriving at each antenna are fed to a common receiver. If the waves arrive at the antennas simultaneously, they reinforce each other, producing a stronger signal. But if the maximum of one wave overlaps the minimum of the other, the two waves cancel each other out and the signal strength falls to zero. The path difference between the antennas — the added distance radio waves from the source must travel from the first to the second antenna — determines which situation will occur. As a radio source is tracked across the sky, however, the path difference continually changes. Thus the waves alternately reinforce and cancel one another, producing what are called interference fringes.

The interference fringes contain two pieces of information: the timing of the fringes, known as phase, and the amplitude of the signal. Analysis of the phase information gives a very accurate position for the radio source. The amplitude of the interference fringes gives the strength of the source's radio emission.

The same principles used in a two-antenna interferometer can be used in interferometers with three or more antennas. The Green Bank interferometer has four antennas, one of which is at right angles to the line of the other three. This arrangement produces even greater accuracy in measuring a radio source's location.

extraordinary behavior: they believed something had to be wrong with the measurements. Fiedler made a mental note to check later and see for himself.

His first task, though, was to systematically recalibrate all the data from the past seven years. He decided to base the new calibration on the amplitude information from several sources. Fiedler spent the following few months writing a computer program to make the necessary calculations. In one night the program processed seven years worth of data from the sixteen quasars.

The next day Fiedler began papering the walls again. The new charts spread into a second corridor. Once again he pulled out a chair, and this time he was pleased with the results. He no longer saw the joint meanderings of the sources, which meant he could trust the new calibration. Next he would have to examine each of the sources carefully and identify variations intrinsic to the source and those caused by scintillation. He could at last begin analyzing the data in earnest.

Accurately measuring quasar intensities is difficult because fake signals often occur in the quasar data. Interference from electrical fences, cars, and satellites; receiver breakdowns; computer malfunctions; and electrical leakage in cables all produce spurious results. With enough patience each problem can be recognized and taken care of, either by making repairs, correcting for the problem, or, if all else fails, throwing out the data. When quasar 0954+658 showed four months of extraordinary variability in early 1981, the NRL astronomers initially rejected the data. Fortunately someone had saved the raw data tapes. Fiedler looked briefly at this raw data during the months he worked on the computer program, but he was not yet aware the raw data had been processed with all the other data.

The Second Step: Interpretation

Because Fiedler was now examining each chart individually, he took a week to reach 0954+658. Then he saw why the data from those four months had been thrown out: the signal indeed varied in an extraordinary manner, like nothing ever seen before. At 2695 MHz the quasar's brightness rose for a week or so and then faded to half its initial intensity in just a few days. The signal then remained low for nearly two months. It suddenly increased again, rising above its usual level for a week before slowly dropping to normal. The entire sequence lasted almost four months. At the higher frequency the quasar's brightness rose and fell four times, on one occasion more than doubling in brightness in a few days.

As Fiedler stared at the charts he experienced that moment a scientist dreams about: the thrill of seeing something no one else has ever seen anywhere at any time. "I was elated," he says, still excited by the memory. "I ran shouting and screaming down the corridors." After working on this project for several months, he knew all the data were consistent and thus that these were not spurious meanderings of the receiver but a real, hitherto unseen phenomenon.

Fiedler's excitement drew a crowd of other NRL astronomers. Each of them stared skeptically at the charts. The signals from 0954+658 looked interesting, but they were too incredible to be real. No source could behave like that. The other astronomers wanted proof before they would be convinced this was a new phenomenon.

Was the signal seen at both frequencies with each of the six pairings possible with four telescopes? Yes, it was.

Was the signal in the raw data? Yes, it could be seen even there.

The skeptics replied: "So what? Perhaps the signal is due to interstellar scintillation." But it couldn't be, because scintillation is *weaker* at higher frequencies and the variations of 0954+658 were *stronger* at the high frequency. Furthermore, scintillation produces brightness changes of only a few percent over weeks or months. This source more than doubled in brightness in just a few days, an effect scintillation could not have produced.

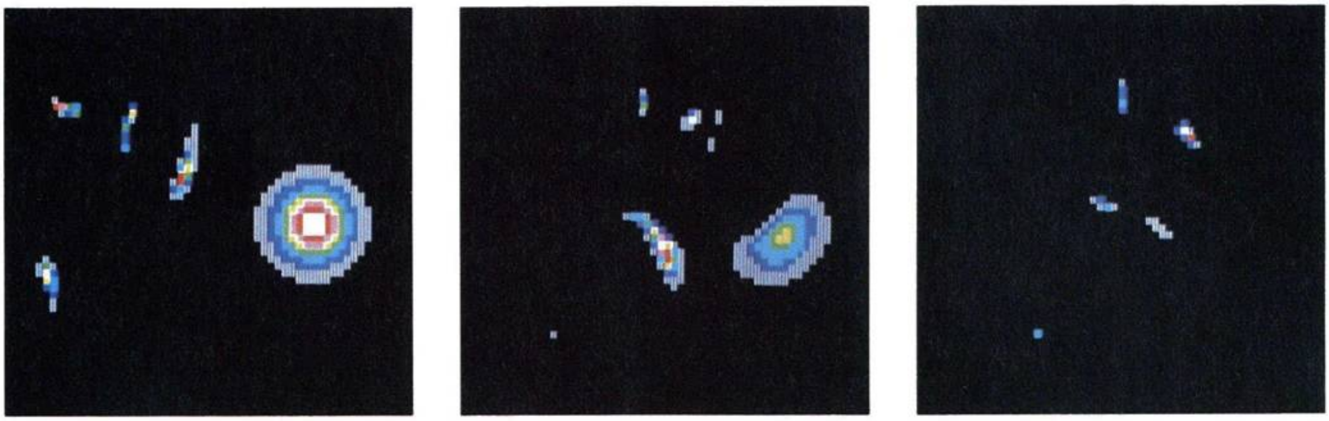
They asked if the variability was intrinsic to the quasar. No, said Fiedler, because the quasar's intrinsic variability has a clear signature also seen in the data. Slow variations at the high frequency are followed by similar variations at the low frequency fifty days later. The new phenomenon occurred simultaneously at both frequencies.

There was one way out. The strange variation had to be caused by something that drifted between the quasar and Earth. This had occulted the quasar at one frequency and caused strong variability at the other. (If data at only one frequency had been available, the phenomenon might well have been ignored or at least misunderstood.) But what sort of structure could cause that?

Fiedler next searched all the charts for further examples. He found two more sources — quasars 1502+106 and 1611+343 — that showed the same odd behavior at the low frequency, although the high frequency signal showed no unusual variations. Nevertheless, these two cases provided the confirmation he needed. Even the skeptics were impressed.

The Third Step: Theory

Fiedler next turned to the difficult task of explaining the phenomenon. At this point Brian Dennison of Virginia Polytechnic Institute and State University arrived at the NRL on a one-year reassignment. An expert on interstellar scintillation, Dennison was immediately excited by the source's behavior and thought some extreme form of radio scattering or scintillation was responsible. Dennison believed ionized gas clouds between the source and Earth produced the scattering.



What will the next Extreme Scattering Event look like? Brian Dennison, Ralph Fiedler, and Ken Johnston have developed a computer model predicting what high-resolution observations may reveal. Just before the ESE structure drifts in front of the radio source (left), the source appears normal and a few patches of emission "sparkle" in front of the structure. As the structure partially occults the source (center), these transitory emissions become more prominent. When the radio source is totally occulted (right), only weak patches of emission remain. The pattern repeats in reverse as the structure advances. Images courtesy Ralph Fiedler.

Fiedler, on the other hand, suspected diffraction — the deflection of electromagnetic radiation as it passes the edge of an object — because the higher-frequency signal showed behavior similar to that seen when the Moon occults a radio source.

Ken Johnston played devil's advocate as the other two struggled with one idea after another. At last they felt satisfied the observations were the result of extreme scattering, and they sent their report to the scientific journal *Nature*. One of the referees *Nature* chose to review their paper was Antony Hewish of Cambridge University, a Nobel laureate in physics. Hewish felt the NRL astronomers were on the right track, but he suggested a few refinements to make their theory work even better. The report was published in the April 16, 1987, issue of *Nature*.

The Extreme Scattering Event (ESE), as it is now called, was triggered by some kind of very small structure with a clearly defined boundary that drifted in front of 0954+658 in 1981. The quasar's angular diameter is only 0.39 milliarcseconds and the ESE produced major changes in the source brightness in fifteen days. Working with these observational parameters and their data at both frequencies, the researchers concluded that the mystery object moved across the sky at a rate of 0.09 milliarcseconds per day. If the object was at the quasar's distance of 1,000 megaparsecs, this angular rate implied an apparent velocity five hundred times the speed of light! Although such apparent velocities are not theoretically impossible, they are highly improbable, and the authors argued that the object had to be much closer.

The researchers next examined the possibility that the object was in our own Galaxy. Traveling at a velocity of 200 kilometers per second, typical of material in the Galaxy's halo, the occulting object would have to be 1.3 kiloparsecs (kpc) from Earth. (It might actually be much closer with a correspondingly lower velocity, but the authors worked with the 1.3 kpc figure.) To cause the two-month minimum seen at 2695 MHz, the object had to be 7 astronomical units (AU) across. An AU is the average distance of the Sun from Earth, so the mysterious occulter is very small by astronomical standards. The radio observations at 8085 MHz showed that at least four or five patches of ionized material also must exist inside this object. These inhomogeneities had a diameter of 0.5 AU (at the assumed distance of 1.3 kpc) and scattered radio waves.

The theory predicted that scattering would bend the low-frequency radio waves *outward* rather than focusing them as a lens might. This meant that as the object first moved in front of the quasar and again when the quasar reappeared, the source brightness would increase at Earth. The structure essentially projected an irregular image, and as Earth moved through this image the radio telescopes observed two maxima separated by a deep minimum.

The scattering effect at the higher frequency is different. Each of the inhomogeneities independently deflected the radio beam so a lot of separate beams emerged from the object. These beams occasionally reinforced each other, producing bright spots. As Earth passed through these bright spots (which is not always the case — this is why 1502+106 and 1611+343 showed no unusual behavior at 8085 MHz), the radio telescopes saw a series of brightness increases at the higher frequency. The theory seemed to fit the observations very well.

The Green Bank interferometer has now observed sixteen quasars for seven years and another twenty quasars for two-and-a-half years. During this time the telescopes have detected four clear events and three less dramatic ones. Fiedler and his colleagues roughly calculated how many ESE structures exist from the number and length of the events and the number and length of time the quasars have been monitored.

If the objects are located in the galactic halo, then one hundred of these structures exist in each cubic parsec of space. If this is correct, there are one thousand times as many of these objects as there are stars. That alone makes the ESEs one of the most startling astronomical discoveries of our age and surely one of the least expected. Interstellar space may be populated with swarms of unseen objects more numerous than stars.

How much matter do these objects contain? The ionized inhomogeneities need to have a density of 4,000 electrons per cubic centimeter to account for the observed scattering in the 0954+658 event. Based on a size of 0.5 AU, the mass of each inhomogeneity is approximately 10^{-14} solar masses and the entire structure's mass may be ten times that figure. Thus each object has a mass about 10^{-7} that of Earth, about equal to that of a small asteroid. The total amount of mass in all of the hundreds of trillions of these objects is then just one hundred solar masses, completely insignificant compared with the one hundred billion solar masses in the Galaxy.

The most intriguing thing about the hypothesized structures, a point the authors of the report hesitated to emphasize but did allude to, is that these objects are not stable. (See "Can ESE Structures Exist?" above.) What is not at issue, however, is that these structures must be more common than stars.

The Next Step: Follow-Up

Dozens of astronomers are prepared for the next challenge: observing an ESE in progress. Fiedler and his colleagues have launched the largest monitoring program ever undertaken on a major telescope. Daily observations of hundreds of radio sources are under way with the 300-foot telescope at the NRAO in Green Bank and will run through next spring. Once astronomers spot an event, other radio telescopes, each performing a different measurement, will quickly join the observational assault on these mysterious objects. In particular, very long baseline observations will reveal changes in the source's structure during the event. If the theoretical predictions are correct, these observations will reveal "sparkling," patches of radio emission that come and go around and in front of the source as the structure drifts by.

Within a year we should know a lot more about Extreme Scattering Events. Only then will we be able to assess the significance of what may prove to be one of the more dramatic and certainly surprising astronomical finds of this century.

Gerrit L. Verschuur is a freelance writer and researcher who lives in Greenbelt, Maryland. He is the author of The Invisible Universe Revealed: The Story of Radio Astronomy, *published by Springer-Verlag.*

Can ESE Structures Exist?

Ralph Fiedler and his colleagues faced a major problem as they struggled to understand the unprecedented radio signals from 0954+658: the hypothetical structures they believe cause Extreme Scattering Events (ESE) are not stable and therefore should not exist. The researchers hinted at this problem in their report in *Nature*: "There are many important questions concerning the nature and stability of these structures that we are unable to answer at present."

Such a situation is not unusual in science. Scientists often present their discoveries before they have worked out all the details. This practice fosters an atmosphere of intellectual adventure in which researchers can pursue alternative implications with open minds. Fiedler's group was convinced that something moving at about 0.09 milliarcseconds per day passed in front of a small-diameter quasar. But what could this "thing" be?

The dominant force holding most astronomical objects together is gravity, which counteracts the disrupting influence of internal pressure caused by heat and high density. The researchers argued that the ESE structures were in our Galaxy — and suggested a distance of 1 kiloparsec — and thus that the objects were very small. If this is true, the radio observations are best explained by a structure 7 AU in diameter that contains inhomogeneities 0.5 AU in diameter with electron densities of 4,000 per cubic centimeter. However, such a small object appears to contain up to one trillion times as much thermal energy as gravitational energy! If such an object could exist for even a moment, it would quickly dissipate because its internal heat energy would overwhelm the force of gravity.

An alternative approach is to assume that the ESE structure is stable and then try to explain the radio observations. The amount of mass required to hold the ESE structure together can be calculated from the structure's diameter and an assumed temperature. To be gravitationally stable, the overall structure must contain as much mass as an entire planetary system and have within it several planetary mass objects (the small inhomogeneities). But these objects are not planets: they have much larger diameters than planets and thus are much more diffuse.

If this is the case, planetary mass structures may be a thousand times more numerous than stars and wander about without accompanying stars. The combined mass of all these objects would be comparable to all the stars in the Galaxy. The implications of this analysis are so far-reaching that in the interests of scientific caution Fiedler and his colleagues set this line of reasoning aside until more observations can resolve the issue.

Another less fantastic explanation is based on the geometry of the mysterious objects. If the structures are really filaments seen end-on, then the electron density might be substantially lower than 4,000 per cubic centimeter. A lower density would reduce the internal pressure, which would allow the filaments to survive longer. Then the mystery is how the filaments form.

Despite this wide range of possibilities, Fiedler and his colleagues essentially had a very simple choice. They knew the size of the mystery object. They could either attempt to explain the radio brightness changes and ignore the stability problem, or they could confront the stability issue and be unable to explain the radio variations.

Like all good scientists, they are able to tolerate the ambiguities in their model until subsequent observations clarify the picture. And it is only through these observations that astronomers can hope to fully understand the mystery of Extreme Scattering Events.

— Gerrit L. Verschuur

ASTRONOMY
Forum

Hot Tub Astronomy: A Star for Everybody

Grandchildren give you a chance to do the things you didn't have time for or didn't think of when you were busy raising your own family.

When the children of our two daughters and son were going to be spending the night with us — all at the same time — while their parents were away, their grandfather wanted to plan a special treat for them.

He decided that if the youngest children took good naps, he was going to let them stay up late, have their first "hot tub astronomy" lesson, and even pick a star for their very own.

Fortunately it was dark and clear that night, as Grandpa, the five excited boys, and two wide-eyed girls marched to the hot tub. I cleverly stayed out to man the towels.

It didn't take long for the youngest girl to spot the star she wanted. She went for the brightest one, and almost before we were started, six-year-old Libby was the owner of Sirius.

Her younger brother, Scott, wasn't happy with anything second to his sister's, but with Sirius spoken for, he would have to choose something else.

"What's second brightest?" he inquired in resignation.

"Canopus can't be seen tonight, too smoggy, and you can't see it from your house anyway, because the star is too far south," Grandpa explained. Scott sat back and stared at the heavens to think about it.

Meanwhile, three of his cousins had been led to choose the belt stars in Orion. It was a natural for the three brothers but posed one problem. Our charts showed the names of the large stars on the corners of Orion but not the names of the center three. It would defeat the purpose if the boys couldn't learn the names of their own stars. I went in to hunt through some more books and star atlases.

Mike, who was eight and could read, had been pouring over the chart with a flashlight. He did not want to make such an important choice based on sight alone. First he would read what else was out there. "Look!" he told his sister, "Cygnus! That's what Grandpa Swan in Massachusetts named his boat. It means swan! Grandpa, I want Cygnus."

"That's a whole constellation. How about the star Deneb in Cygnus?"

"Where is it?" Mike looked up hopefully.

"It's on the other side of the house. I'll have to show it to you later. But it's a good choice. Very easy to see from your house."

I returned with the names of the belt stars. The left belt star was named Alnitak. It would go to the oldest of the three brothers, Tripp, who was seven. He repeated the name while staring at the star. The second brother, Grant, would have Alnilam. And three-year-old Andrew would get Mintaka. Fortunately the name was easy for him to pronounce.

Now all the grandchildren wanted to look at their stars with the binoculars. But when the children held the expensive binoculars in the hot tub, Grandpa became nervous. The children were never quite able to find anything with them, so Grandpa came up with a way to keep the binoculars dry and show the children their stars. He held the binoculars and centered the star in them. Then he moved his right eye to the left eyepiece. The child put his left eye on the right eyepiece, so they were cheek to cheek, each looking through a monocular.

The tub was bubbling over with cookie crumbs and excitement. Scott tried again to find something equal to his sister's star. "Isn't there anything brighter than Sirius?"

"Yes," his grandfather answered. "The Moon and Venus are brighter. But Venus would be a lot of work for a five-year-old. It's a planet and doesn't stay in the same place the way the stars do. If you want to do the work of tracking it, it's yours."

"I will," said Scott eagerly.

The eldest girl, Ashley, chose Polaris for its simplicity.

Everyone happily enjoyed his or her choice, and the word spread.

Our youngest daughter's two boys soon asked for stars of their own, and Grandpa obliged. J. J. chose Aldebaran because he liked the Bull, and Robert liked the Pleiades. Maybe it was all of those sisters, something they were a little short of.

Months passed. Bob wondered if the children had kept in touch with their stars. When the three brothers returned, they were full of excitement. Tripp rushed to his grandfather.

"Guess what, Grandpa! Today in school my teacher talked about stars. I told her I had a star of my own and showed the whole class Alnitak. Then I pointed out my brothers' stars Alnilam and Mintaka and Libby's star Sirius. All of the kids thought that was really 'rad'! Some of them came up to me and asked if my grandfather would give them a star too. Will you?"

Bob laughed. "How do you like that! As if we don't have enough kids, I just inherited the whole third grade!"

"Rad?" I said.

"You know, Grandma, radical! Great!"

I had an idea. "Tripp, tell the children there are plenty of stars for everyone. They can just go out and pick one. Tell them to look carefully at the stars around their chosen star, so they can find it again. Then they should get someone to tell them their star's name. After they can find the star and say its name aloud on three differ-

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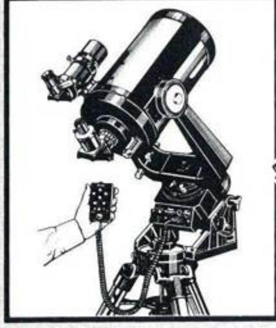

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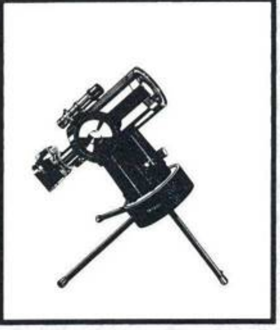

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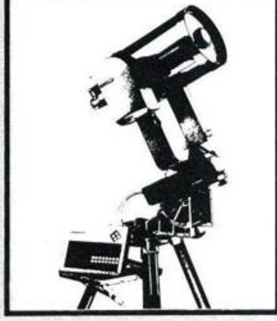

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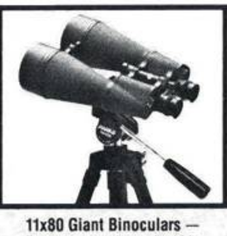

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ent nights, the star is theirs forever."

"Oh, that reminds me," said Tripp. "Mom said to have Grandpa help us pick a new star."

"But you boys already have the three neatest stars in the sky." I said.

"What do you need a fourth one for?"

"Because," answered Grant, "we're going to have a new baby . . . !"

". . . brother," added Andrew.

Beverly Mosier
Laguna Beach, California

The Primal Fear: Are We Alone?

What compels us to explore space? What are we looking for? What drives us into the heavens? We humans have many excuses: some claim it's the adventure, others claim that lust for money and power drive men to new lands. Today we speak of "science" and the quest for knowledge.

But I believe the real reason we press outward is the primal fear of being alone in the universe. This is the dark side of space, the primal impulse to find companionship in a universe too vast.

During the late 1800s two astronomers accelerated man's primal impulse by announcing they had found artificial structures on Mars. In 1877 Giovanni Schiaparelli reported observing "canali," aqueducts constructed by Martian engineers to transport scarce water from the polar regions of Mars to the rest of the planet. This idea was popularized by Percival Lowell, who used a 24-inch Clark refractor to make many sketches of the Martian canals. The public loved the idea, but scientists rejected it.

Four score years later in 1956, space flight was still in the future, but man had already traveled to the fringes of space in the Bell X-2 rocket plane. In September 1956 the X-2, piloted by Captain Ivan C. Kincheloe, set a manned altitude record of 126,000 feet and a manned speed record of 1,900 miles per hour. The news media immediately proclaimed that with the flight man had reached "the very regions of outer space."

After the successful X-2 flight the United States began experimenting with prototype Thor and Jupiter intermediate-range missiles. During 1957 these vehicles achieved unprecedented altitudes during test flights.

It was a wonderful time for space exploration. We were about to arrive and knock on the door of the universe. Would anyone answer it?

Then on October 4, 1957, the Soviet Union launched the first orbiting satellite, *Sputnik I*, much to the shock of the rest of the world. Two months later the Soviets launched *Sputnik II*, a satellite that carried the first live cargo, a small dog named Laika.

Suddenly humanity found itself free of the gravitational constraints imposed by Earth. We had at last achieved the capability of exploring distant worlds with robot probes.

Man's attention turned to Mars and Venus. These worlds captured our attention and imagination, not merely because they were the nearest planets to us but because there was the chance (some even said certainty) they harbored some form of life. The Moon, by contrast, was already known to be a "dead world."

Mars had its mysterious canals. Even for those skeptical of the canals Mars did have an undisputed "wave of darkness" that began each spring at the polar caps and spread to lower latitudes at a rate of several miles per day. To some this wave of darkness represented spring growth spawned by the melted polar cap ice.

While we thought we knew a great deal about Mars, Venus remained very mysterious. Unlike Mars, Venus is shrouded in a dense blanket of clouds, keeping its secrets behind an impenetrable veil.

Although we could not see the surface of Venus directly, we were still able to speculate about what existed beneath the cloud decks. Astronomers proposed three ideas about Venus' composition. The first, called the "hot surface model," supposed that below the clouds the surface of Venus was incredibly hot. The second proposed that the surface of Venus was covered with a sea of hydrocarbon goo. The third model, the so-called wet Venus model, proposed a dense, steamy atmosphere, possibly thick with alien life.

However, the third model with its wonderful potential for life ran into problems. Earth-based microwave studies of Venus revealed a radio spectrum more consistent with the hot surface model.

In the late 1950s the United States planned to send probes to both worlds. Venus was to receive a flyby visitor in 1962 and Mars in 1965. These *Mariner* probes would be the first planetary spacecraft ever launched from Earth. There were great excitement and apprehension over these missions, because there was no precedent for what we were attempting.

In 1962 two Atlas-Agena B rockets stood on the pad at Cape Canaveral, ready to launch twin *Mariner* probes toward Venus. It was about to happen. Mankind was going to begin a great period of planetary exploration and discovery.

The first probe suffered a launch failure but the second, *Mariner 2*, made a historic flyby of Venus on December 14, 1962, after a 109-day journey. During the brief, 35-minute flyby, *Mariner 2* was programmed to make critical microwave observations that confirmed the hot surface model was correct. The surface of Venus was not just hot: it was hellishly hot.

Reaction to this revelation that Venus was so hostile was not just disappointment but a deep and widespread disappointment. Of course this was the first world we had explored, and there was no precedent yet of what to expect from such negative findings.

In 1965 with the *Mariner 2* findings behind us, we eagerly awaited the first flyby of Mars. After a journey of more than seven months, *Mariner 4* passed within 6,100 miles of Mars and took a series of twenty-one photographs of the surface. One photo per day was sent back to Earth while we waited and held our collective breath. What would be revealed? Would we find canals or Martians?

No. For the second time we experienced the sharp disappointment of failing to find life. We had examined two worlds up close, but neither lived up to our hopes.

Human beings obviously have a strong need to find life apart from what has evolved on our planet. Our need is so compelling that we now look hopefully to other worlds within our solar system. Some scientists believe life may have developed on Saturn's satellite Titan, an object with a dense hydrocarbon atmosphere. Others say the Jovian satellite Europa could have developed life under an ice-covered ocean.

Our search for extraterrestrial life is not confined to our solar system. Since 1964 when Frank Drake first revealed that he had conducted a 400-hour radio search of two nearby stars for patterned signals, there has been a large number of additional and more comprehensive radio searches aimed at detecting extraterrestrial radio noise.

What compels us to search for life in the universe? Certainly scientific curiosity and the "need to know" are part of the answer. The search for new knowledge and the refining of our philosophy of why we are here also account for part of the answer. But neither is the real reason we explore space and seek new life. Quite simply, we do these things out of fear — fear of aloneness.

Mankind's exploration of space is due to a fear of being alone? Absolutely. This fear is understandable when we examine it from a historical

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perspective. Before the time of Copernicus man was located in the center of the universe. The Sun, Moon, planets, and all the stars circled Earth. It was a universe of perfect structure and order with Earth at its very core.

Man saw his position as one of great and irrefutable importance. Were not all the heavenly bodies circling around the abode of mankind?

But Copernicus questioned this belief. He favored a universe with the Sun at its center and Earth in the demoted position of an attendee of the Sun. His theory was published in 1543 as Copernicus lay on his deathbed. This timing was no coincidence. Copernicus knew the magnitude of the controversy that would follow and wished to spare himself from persecution.

Copernicus' work had a great unsettling effect. Our security blanket had been lifted, and for the first time man's central place in the scheme of things was questioned.

Mankind's next demotion came in 1609 when Galileo first turned a telescope to the heavens. It seemed that the observable universe in which man was located wasn't so "perfect" after all. Worst of all, Galileo was reporting new discoveries and revelations that refuted man's central status in the universe. To Galileo the whole universe seemed to be functioning in an independent and orderly manner without the slightest regard for man's presence.

This demotion in mankind's perceived importance was too significant to ignore. Major social institutions attacked the astronomer's conclusions. Some, fearing loss of stature, openly criticized the "devious illusions" created by the telescope. Galileo was eventually forced under threat of violence to revoke many of his findings.

However, despite attempts by many individuals to seek refuge in traditional beliefs, new discoveries forced us to realize that man did not occupy a unique position in the universe. Astronomers told mankind the stars were suns like our own and that our Sun was only one of billions. Faced with the rather unsettling fact that, statistically speaking, we were insignificant, we turned to other worlds. And the universe continued to expand.

The crushing blow came in 1924 when astronomer Edwin Hubble discovered that "spiral nebulae" are indeed immense collections of stars, gas, and dust lying at extremely remote distances. The heavens once again expanded and man's position in the universe suffered another setback.

Today we stare into the night sky knowing the universe is an immense place. The thought that no other eyes but man's exist to look upon the endless splendors of the universe is too frightening to bear. So we continue to search for life.

We are compelled to keep searching. And when we fail to find life elsewhere, we invent new explanations for our lack of success. Each new idea gives us renewed hope. Life is there, we tell ourselves. It is just one step beyond the point where we failed to find it. But we must tell ourselves this, because we are faced with the possibility that in all the enormity of this universe we are alone. And loneliness is the greatest fear of all.

Frank Apsi-Ridolfo
Bloomfield, Michigan

Eight Ways to Combat Astronomy Burnout

No observer is safe from astronomy burnout.

Deep-sky observers suddenly find that all other deep-sky objects look the same after they've seen "showpieces" like the Orion Nebula and the Pleiades.

Planetary observers tire of looking at the same old Moon, and the seeing is always too lousy to study the festoons in Jupiter's cloud belts. And whenever something worthwhile happens, like a lunar eclipse or two simultaneous satellite shadows on Jupiter, it's cloudy.

Astrophotographers suffer from equipment frustrations. When someone else takes much better photos with a modified C14, why should you even attempt astrophotography with your backyard C8?

If these situations sound familiar, you too are probably suffering from astronomy burnout. But you're not alone. I have been through the same doldrums, and I've found some ways out.

The first solution to burnout is learning some "real" astronomy. Cloudy nights are perfect for reading a book about astronomical theory, like stellar evolution, galaxy dynamics, or planetary geology. The more you understand about what you observe, the more you will enjoy what you see.

Open clusters, for instance, will never look the same. Learn to search for intensely hot, short-lived blue stars or red giants and dwarfs, and you'll never grow tired of looking. You'll wonder at the age of the cluster and look for details you never imagined existed before.

Many community colleges offer evening astronomy courses that are also ideal for amateur astronomers who want to add astronomical theory to their observational knowledge.

Astrophotographers fed up with photographing the same objects over and over again can take a step backward to simple piggyback techniques. The simple 50mm or 135mm lens on your camera is a powerful tool for locating and tracking asteroids and comets, monitoring variable stars, capturing unexpected meteors, and discovering novae. Learn to study your photographs carefully to see what you can learn from them. Who cares if you took an ugly picture if it shows Mira at minimum light?

Another way to record what you see is sketching planets and deep-sky objects. Drawing forces you to concentrate on detail as you sketch your subject, and you will be able to see more detail after a few drawing sessions at your eyepiece.

The time sketching requires brings up another point. In this age of computer-controlled telescopes beginning amateurs tend to "observe" as many objects as they possibly can in the shortest time. This can bring on burnout in record time.

The antidote is taking the time to observe. Look at each object for a full five minutes. You will witness the detail that only becomes apparent during extended viewing.

And don't forget about binoculars. The wide-angle vistas of the night sky offered by a pair of 7x50s or 11x80s can be breathtaking! Large objects like the North America Nebula and clusters like the Pleiades take on a new dimension when viewed with both eyes. Set up a lounge chair, lie back, and ponder the mysteries of the universe.

Don't observe the sky in a haphazard way; you'll run out of things to see. Make a detailed list of objects for the night, including some superb and some obscure deep-sky sights.

Getting together with other amateurs for an organized observing program is yet another way to avoid burnout. The social aspect of amateur astronomy is one of its most enjoyable parts.

A last but important deterrent to astronomy burnout is teaching amateur astronomy to others. Watching the reaction of a novice observer getting a first look at Saturn's rings can bring back the thrill you experienced when you first viewed the ringed planet.

Set up a night of viewing for your favorite class at the local grade school. You might even encourage an interest in astronomy as a hobby or profession. I can't think of a more rewarding aspect of amateur astronomy.

Amateur astronomy is a hobby, not a job. Don't feel compelled to take photographs or to make some scientific contribution. You are an amateur astronomer for your enjoyment. Enjoy!

Hal Jandorf
Moorpark, California

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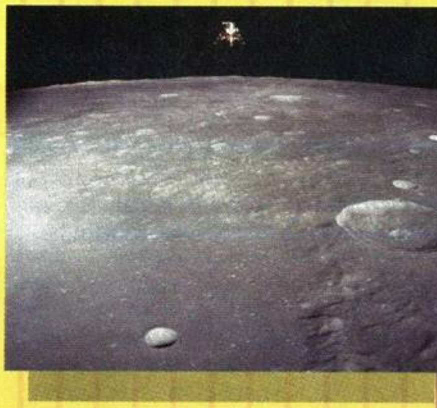

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In Focus

A Great Future in Space

Sir / I agree with Martin Sickler's "Winning the Battle of the Space Budget" (Forum, August, 1987). Many pro-spacers do not even realize how much support NASA has in Congress, but the American people need to tell our leaders in a unified voice that most Americans want an expanding space program.

I have written letters to senators and representatives and their responses demonstrate their enthusiastic support of NASA and science and technology. NASA's budget could be increased if more Americans were willing to jump on the bandwagon.

Let's get organized and lead this country toward a great future in space.

F. David Plummer
Machias, Maine

Sir / Mr. Sickler hit the nail on the head about the ability (or inability) of pro-space groups to affect the NASA budget and programs in Congress.

One of the goals of the newly formed Florida Space Society is to bridge all pro-space groups with some type of council organization. Our group has already started this by bringing together five pro-space organizations during our recent Space Week '87 activities in central Florida.

Please feel free to contact me for more information.

Jim Harris, Director
Florida Space Society
P.O. Box #291
Sharpes, FL 32959

Texas Troubles

Dear Sir / It was quite a surprise to see my fuzzy face staring back at me from page 38 of the September issue, and I was delighted to see two articles on the Texas Star Party. However, your description of my astrophoto rig in the "Special Report: Riverside and the Texas Star Party" contains a slight inaccuracy: Dry gas is pumped into my Schmidt camera to dehumidify the interior, not cool the film.

Robert Reeves
San Antonio, Texas

Dear Sir / I enjoyed the "Special Report" on the Texas Star Party in your September issue, but I wanted to point out that our 24-inch telescope, pictured on page 40, was built by Joe Pearson and John Dutton of Oklahoma City, not by me and Phillip Scott, and co-owned by John Elrod.

David Higgins
Krebs, Oklahoma

Dewing Solution

Sir / After reading "Thunderbolts Can't Short-Circuit Texas Star Party" by Jeff Kanipe (Forum, September 1987), I wanted to offer a solution to the dewing problem mentioned at the end of the article.

I had the "wet lens look" until I cut a 50mm-diameter hole in the base of my 300mm catadioptric lens case and friction-fitted the case to my normal 50mm lens. It works fine as a dew shield, and when I want to use the shield as a lens case, I simply use a heavy cardboard "bottom" to cover the hole.

Ron Paul Smith
Sharon, Massachusetts

Stop-Down Mask for Double Star Observing

Sir / Many of us with large, short focal length telescopes have had to learn to live with a single vane diagonal support, which is often centered off-axis. As a result of this configuration, scattered light can make close double star images appear "dirty." Even the easier double stars show this "flare" of light between component stars.

To solve this problem, members of the Carolina Skygazers have learned to use an off-axis stop-down mask for fabulous double star performance. Less light enters the tube, so the images are easier to see. The diagonal support is out of the optical path, so no light scattering occurs. In effect the focal ratio is increased because of a smaller diameter mirror surface, while the focal length remains the same.

To figure the size of our stop-down mask, we subtracted the axis of the diagonal mirror from the primary mirror size and then divided the result in half. We placed cardboard on the top (open end) of the tube and positioned a drawn or cut-out circle so the diagonal support doesn't get in the way of the image by looking into the focuser while adjusting the mask.

We've found that our telescopes with stop-down masks rival the performance of longer focal length instruments, often resolving stars at the theoretical limit of the scope.

M. Leon Knott
Curator of Physical Science/
Director of Planetarium
Museum of York County
Rock County, South Carolina

Space Debris Crisis 'Impending' for Years

Sir / "The Impending Crisis of Space Debris" by Joseph A. Lovece (August 1987) predicts that as space becomes more cluttered with debris, the potential for a very expensive disaster increases. This made me smile, because I had made a similar prediction in a speech to the Sixth Congress of the International Astronautical Federation in Copenhagen, Denmark, in 1955. The key word then was "eventual" instead of "impending."

My speech got almost unanimous scowls. This was understandable, because no one had orbited anything yet. Most rocket junk was falling into the ocean and not making it into orbit — and not intentionally either. No one was interested in space debris when no one had proved that anyone could orbit anything. Success first; then talk about problems.

My paper was positive, pleading the utility of artificial satellites, but people often notice incidental remarks rather than the main thrust of the paper.

Heyward E. Canney, Jr.
Bowie, Maryland

Welcoming Winter

Sir / I arose at 3 a.m. on August 13, to view the Perseid meteor shower. As I stepped outside I noticed that Jupiter was well placed for viewing, so I took a quick look at it. Then I got down to business and watched the shower. Despite the glare of the Moon, which was only 45° from the radiant, I managed to see thirty meteors in 50 minutes. The brightest meteor was about magnitude −1 and left a long trail visible for 5 seconds.

I took one more look at Jupiter before I went in. I was surprised to see a very bright spot about 1″ or 2″ from the edge of the disk. As I watched, two things happened: the spot, which was Europa, slowly moved out of transit and into the blackness of space, and a meteor flashed across the field of view less than 1′ from the King of Planets!

I then looked eastward and saw my favorite constellation, Orion, rising in front of the house. I dragged my 8-inch telescope to the only spot in my yard with a clear view in that direction and saw the Orion Nebula for the first time in months with both my low-power and high-power eyepieces. Although the nebula was very low in the sky, it was like a cold glass of water to a man who had been lost in the desert. The soft clouds of glowing gas and the Trapezium were beautiful.

That was the most rewarding two hours under the stars I've ever spent. Let the winter come — I'm ready!

Thomas Rankin
Highland, New York

Let's Keep Our Distance

Sir / I'm tired of hearing astronomers moan about how far away everything in the universe is from us. This is really not the case. Most of the objects in the universe are in nice, easy reach; in fact, many objects are far too close. Consider these examples.

The Milky Way: We are surrounded by it in every direction. Looking along the plane we are swamped by a profusion of gas and stars. Too bad if you want to study a little star on the opposite side of the Galaxy. The Milky Way blots it out. How nice it would be if the Milky Way was 500,000 light-years away and face on. Then it would be bigger than the Andromeda Galaxy and a lovely object to view.

The Moon: Too close! Every two weeks it spills light all over the sky. Too bad if you've spent two hours setting up your telescope and star charts. Too bad if you are trying to glimpse the 15th-magnitude star in the center of the Ring Nebula. Up pops the Moon, grinning and upstaging everything in the sky. And then you blind yourself trying to look at it through a low-power eyepiece.

The planets: Again too close. Always whizzing around the sky so you can't keep track of them. Mercury is the worst: It's never in the same place twice. Venus likes to linger in the morning sky, foiling any observer when tiredness and cold get the better of him or her at 2:30 a.m.

The Sun: Too close, much too close. Astronomy grinds to a halt twelve hours out of every twenty-four. If the Sun were removed to a distance of 10 parsecs, it would be a lot more convenient for astronomers. This would mean you could do your observing in the middle of the afternoon.

Quasars: The closest is only about 3 billion light-years away. That's too close for comfort. Imagine one in your backyard, hopping and jumping all over the place. You'd soon agree that the farther you are from a quasar, the better.

Brad Wilson
Swansea, Tasmania, Australia

Highlighting Constellations

Sir / I traced the constellations on your Star Dome map with a yellow fluorescent Hi-Liter, so when I'm at the telescope with a hidden ultraviolet light shining on the map, only the highlighted areas show up. Because these areas cover a small portion of the page, night vision isn't harmed. The constellations show up like magic.

James A. Doggett
Fairfield, Iowa

Behind the Scenes

Relaxing in the Universe

In the midst of the holiday bustle, why not take time out to sit down with ASTRONOMY, relax, and stop thinking about whether to buy Aunt Martha a reindeer sweater or Uncle Morton a fish tie? Instead, we invite you to consider some fundamental astronomical questions.

For example, how do spiral galaxies — those ragged yet precise swirls of stars and gas — get their shape? What are we seeing when we look at spiral arms? How does a flattened disk of gas sustain structure across tens of thousands of light-years? What forces shape these grand designs of nature? Our feature article has some answers — and poses some questions — that will take your mind off shopping.

Or consider the mystery of the Extreme Scattering Events in Stellar Frontiers this month. A year ago no one knew our Galaxy was loaded with these crazy, impossible little squibs of gas or that these objects might outnumber the stars. What are they? Calculations show such small gas clouds are not stable and should fly apart unless . . . what? Unless they aren't what they seem to be, and nature has fooled us again. One thing is for sure: A lot of astronomers are waiting for the next Extreme Scattering Event to occur.

If you're tired of winter snow already, we have some articles that will let you overcome that "gray skies and slush" depression and dream about high-tech observing. Consider how it would feel to capture the outermost tendrils of gas around the Orion Nebula with a 30-minute exposure on a night when you could almost freeze to death. An absurd fantasy, but people who've done it wrote this month's Photography in Astronomy.

Or try this fantasy on for size: What could a computer do for your observing? Two hundred deep-sky objects per night? Five hundred? A thousand? Well, we checked into the new world of computer-aided observing and report our results in this month's Equipment Atlas. Prices are a bit steep, but the stuff works.

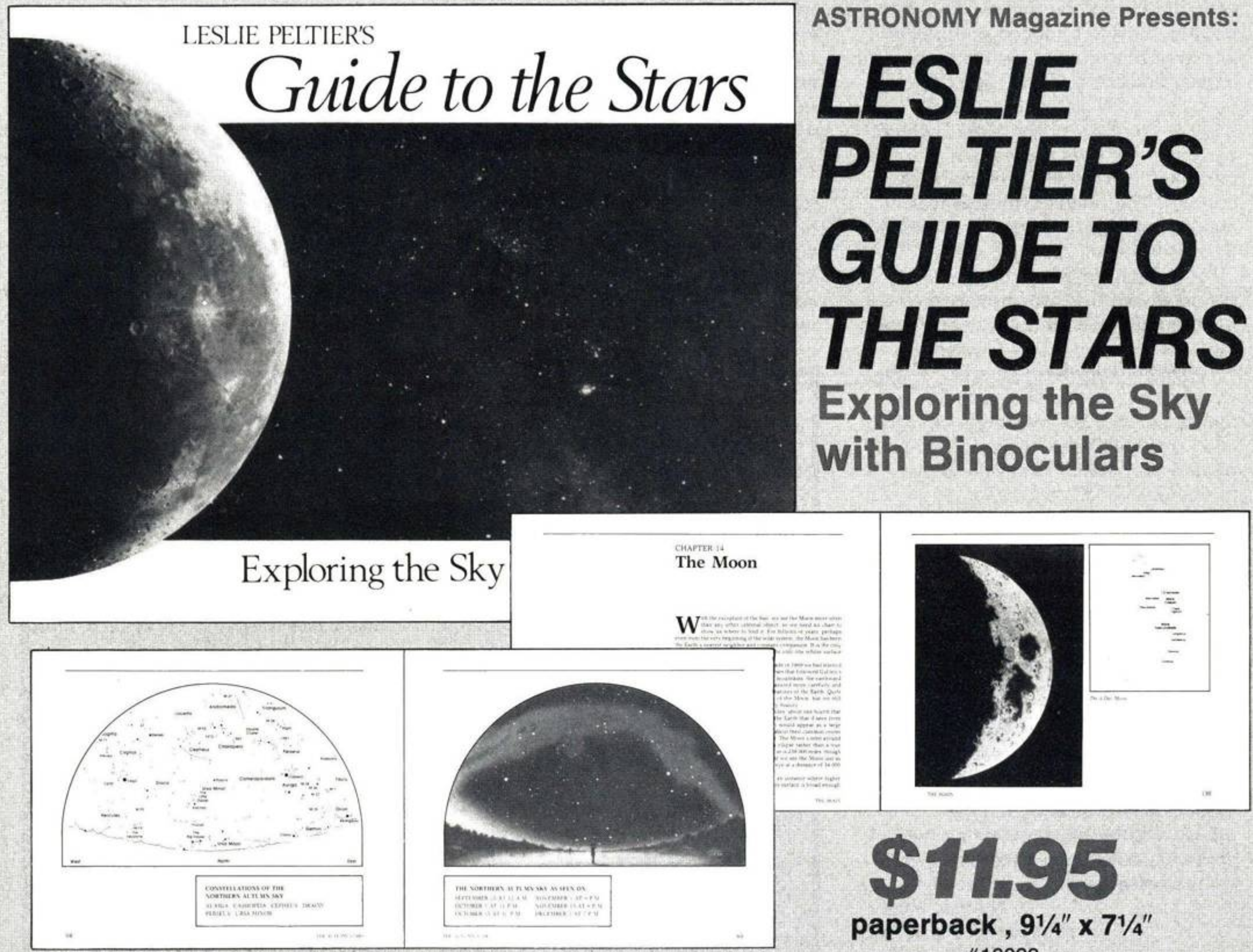
Back in the world of cold winter reality, you'll have to brave the cold if you want to go comet hunting or see Comet Bradfield this month. Ask Aunt Martha for a newfangled version of Grandma's "long woolies" and head for dark skies. And by the way, I'm sure Uncle Morton really wants a fish tie!

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

Explore the nighttime sky, with one of the great amateur astronomers as your guide!



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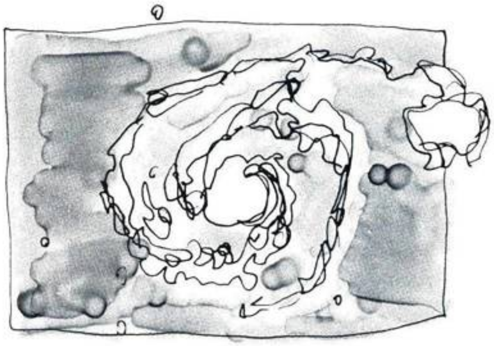

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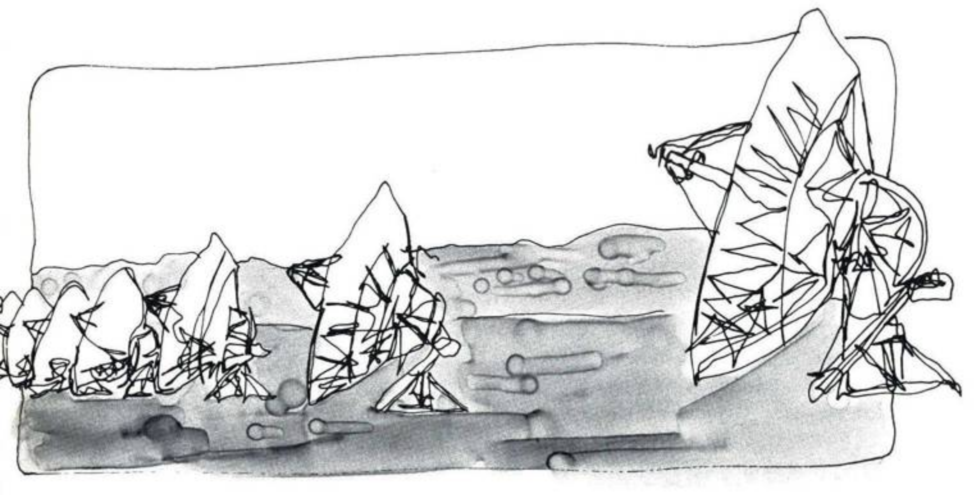

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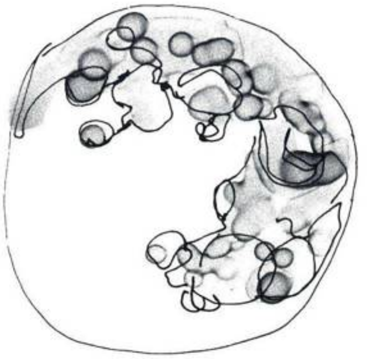

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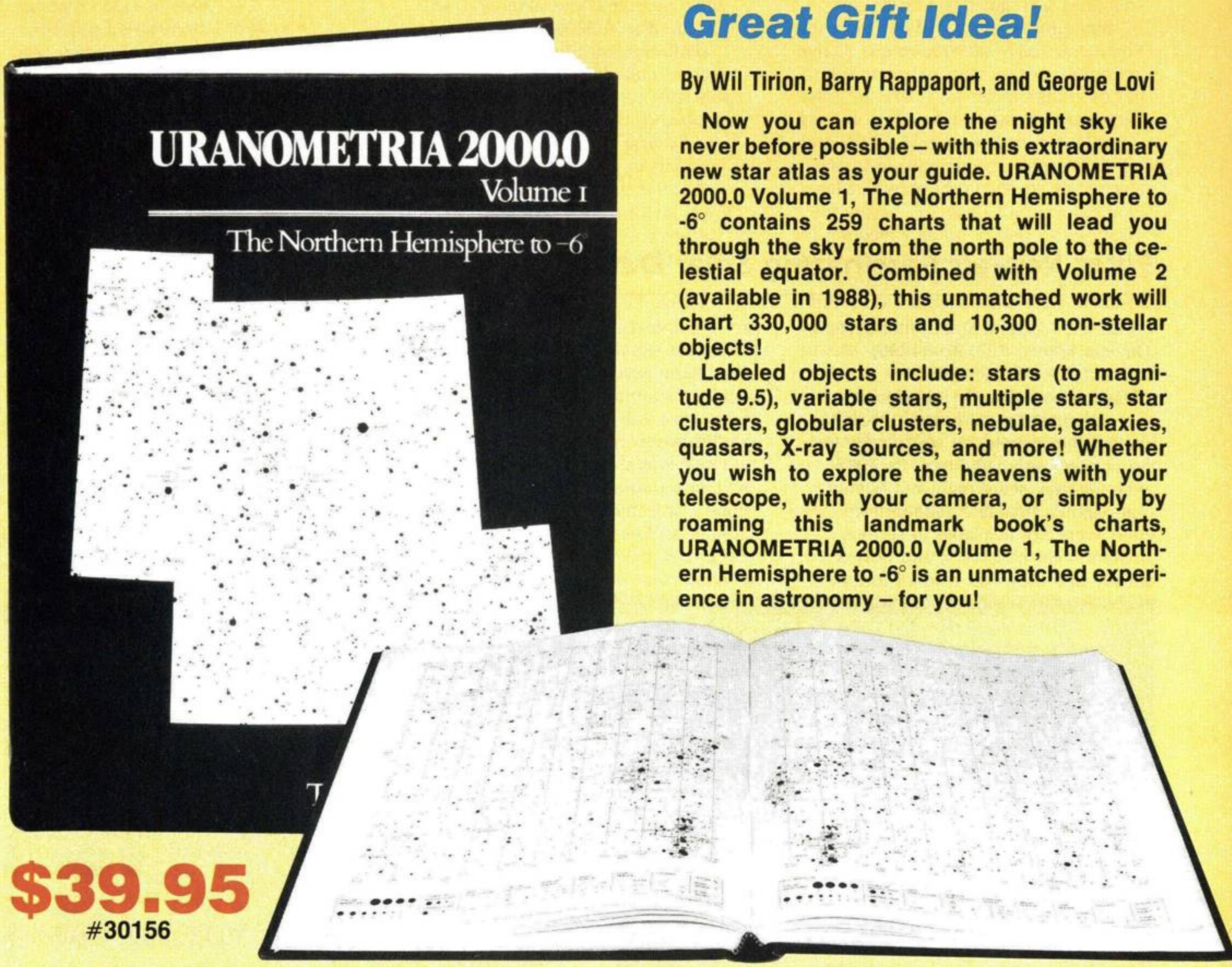
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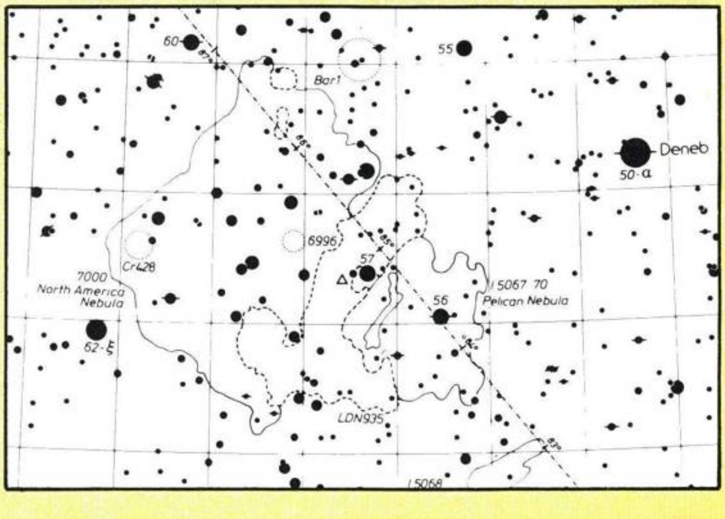
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ASTRONOMY
Reviews

Filter Reveals Fascinating Solar Detail

T-Scanner, H-Alpha Solar Filter System, (DayStar Filters, P.O. Box 1290, Pomona, CA 91769), $995.

DayStar has recently introduced a new 0.9-angstrom bandwidth H-alpha filter system developed specifically for the amateur solar observer. Its $995 price tag may seem high, but twenty years ago comparable subangstrom filters were not available to serious amateur solar observers; and only a decade ago they cost a small fortune. Recently refined manufacturing techniques and increased demand have lowered the cost of these filters and put the filters within reach of a growing number of solar observers.

The same company also manufactures H-alpha filters with bandwidths as narrow as 0.4 angstroms, which sell for three to four times as much. These narrower band filters reveal greater disk detail, of course, and need a power source to keep them heated and centered on the H-alpha line of the spectrum. Broader band filters do not require electrical power to keep them centered; instead, they are adjusted by a fine tuning knob. The lightweight, compact T-Scanner uses a tuning thumb screw and requires no power input, which keeps its cost down. It's perfect for use with Schmidt-Cassegrain telescopes or refractors, for which it was specifically designed. You can take it anywhere without concern about a suitable power source.

The Sun is a low-contrast object and the H-alpha absorption band at 6562.8 angstroms is only 1.2 angstroms wide, so you'll need a filter system with at least a halfband pass of 1.0 angstroms or less to get the needed contrast for full-disk H-alpha observations. This system is designed to operate throughout the ambient temperature range of 32° F to 100° F. It works best when the relative humidity and temperatures are at comfortable levels.

For safe viewing and greater detail, all of these subangstrom filter systems require a nominal focal ratio of f/30. If you own a 4-inch f/15 refractor, you'll have to reduce the aperture by two inches and use a suitable on-axis prefilter mounted in front of your telescope's objective lens. DayStar calls its prefilter an Energy Rejection Filter (ERF). It blocks out 80 percent of the off-band solar energy and keeps the telescope and filter optics cool. If your scope is an 8-inch SCT, you'll need a 2.5-inch off-axis ERF. Either one will cost an additional $175. Don't attempt to use this or any other make of H-alpha filter without a prefilter. In time you could easily ruin your filter.

The T-Scanner H-alpha solar filter by DayStar Filters.

I ran the T-Scanner through its paces during last October's partial solar eclipse with three telescopes: a 4-inch, f/15 refractor; a 5-inch, f/10 refractor (both with an on-axis ERF); and a 4-inch, f/12 SCT with an off-axis ERF to give me a nominal f/30 light beam. The T-Scanner accepts standard 1.25-inch-diameter eyepieces. A 40mm eyepiece with a black rubber eyecup gave best results because it kept out unwanted extraneous light and helped the eye adapt to the deep red color of H-alpha. A suitable alternative would have been a black towel.

The initial test was disappointing. I saw no prominences, no flares, and only one sunspot. I carefully adjusted the fine tuning knob several times, but still saw nothing. My heated, higher contrast DayStar 0.8-angstrom filter showed basically the same thing. Except for the Moon passing in front of the Sun that day, there just wasn't much happening no matter which filter I used.

Since then I have tested the T-Scanner several times with the same equipment. My scopes and the T-Scanner were always carefully checked for dust particles, moisture buildup, or worse yet, fingerprints and smudges on the optics — any of which will lower contrast dramatically. Clear blue skies with puffy cumulus (fair weather clouds) enhance the filter's performance. Morning testing often gave me perfect seeing conditions before local, central Florida humidity had a chance to build up. Of course these rules are true for any type of astronomical observing.

I made additional tests under much better seeing conditions. During one session the T-Scanner vividly showed a large prominence on the Sun's limb, as well as two small sunspots that seemed to be associated with a minor flare that disappeared within minutes.

The following day the prominence rotated onto the Sun's disk. (When this happens, the prominence is called a filament.) Although my temperature-controlled 0.8-angstrom filter showed the large filament with greater contrast, I could also see it easily with the 0.9-angstrom T-Scanner. On the other hand, my tilt-type, broader-band 1.5-angstrom filter did not reveal it at all.

Although the T-Scanner is not designed for full-disk photography, it will reveal individual features under ideal observing conditions. I loaded my SLR with Kodak 2415 film. The camera is well suited for this type of photography because it is equipped with a clear glass (aerial) screen, a 6.5x critical focusing eyepiece with a black rubber eyecup, and of course, a standard cable release.

The bracketed shots I took of a prominence, a filament, and a sunspot showed the detail of both the prominence and the sunspot, but the filament was not recorded.

My main criticism of the T-Scanner is the rather large filter tilt required to bring H-alpha detail into view. I'm convinced this was due to the 95° F temperature during several days of testing. After all, this was very close to the manufacturer's 100° F temperature limit.

Tilting an ultra-narrowband filter will slightly broaden the passband, which results in lower contrast on the disk. At more comfortable temperatures the filter required less tilting, which results in increased contrast. Prominences are broadband features, so they were always observed. Recognizing the ambient temperature limitations inherent to tilt-filter systems, DayStar fabricates T-Scanners to function within the user's expected temperature extremes. Anyone ordering one should specify local temperature extremes. Unfortunately I did not!

This filter system is perfectly safe to use and simple to operate. Detailed instructions are packed with each system in a fitted ashwood case.

The T-Scanner works equally well with refractors and SCTs without requiring the adaptor heated filters require when used with such scopes. It offers greater contrast for solar disk features that lower priced, broader bandwidth filters cannot offer. It doesn't match the visual or photographic quality of my DayStar 0.8-angstrom comparison standard, but it was not designed to do so. On the positive side, its cost is hundreds of dollars less.

The Sun is now approaching its maximum sunspot level, and that means dramatically increased solar activity. If you want to observe all of this action and utilize your scope to its fullest, the T-Scanner H-alpha filter system is worth looking into. Without doubt, this is the best H-alpha filter system available in its price range.

— Donald F. Trombino

Floppy Almanac Is a Real Deal

The Floppy Almanac, computer ephemeris program designed for IBM PC compatibles, (U.S. Naval Observatory Nautical Almanac Office, U.S. Government Printing Office, Washington, D.C., 20402, 1987), $20.

"*The Floppy Almanac* is a program for MS-DOS-based microcomputers which reproduces the data contained in the major sections of the Astronomical, Air and Nautical Almanacs to full precision. The time span of each edition of *the Floppy Almanac* is 400 days: one calendar year plus about two weeks overlap into each of the adjacent years." So states the introduction of the user's guide to one of the best deals in astronomy software.

If you need accurate positions of the Sun, Moon, planets, and stars or desire to calculate the time of certain lunar phases, satellite transits, or rise and set times for the Sun and Moon, *The Floppy Almanac* is a resource beyond comparison. The program was first released in 1987 and has more than proved itself a valuable observer's companion. Although I had access to the 1987 version, the 1988 *Floppy*

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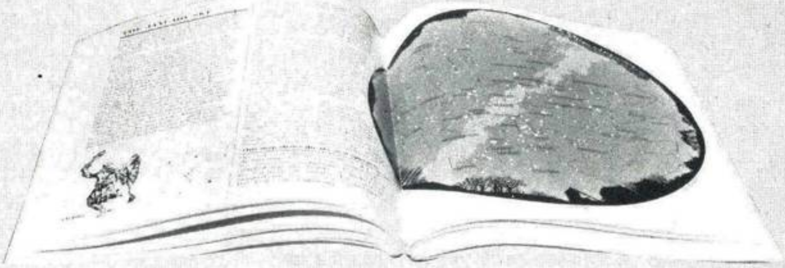

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Almanac will be similar in most respects.

The Floppy Almanac is available in two versions: an arithmetic coprocessor version for computers with an 8087 chip and a software math version for computers without this chip. The 8087 version is about five times faster than the software math version.

After a lengthy download from a bulletin board (ASTRO at 202-547-4418), I ran the program by entering "FA87C." FA stands for *Floppy Almanac*, 87 for the year, and C indicates the 8087 math coprocessor version. I was able to follow the menu that appeared and from there ran off some simple calculations. This is an important first test I give all new software. *The Floppy Almanac* passed admirably, so I got out the documentation and set about trying to learn the software's features.

Perhaps the quickest way to summarize what is available in this program is to describe the nine items on the menu. The menu contains the selections listed below, unnumbered. If you do not read the documentation, it takes a bit of experimenting to discover that typing "pos" (or "POS," because the program doesn't care about the case) gets you into the section on position calculations. All that's needed is enough leading letters to uniquely distinguish your choice.

Positions of the Sun, Moon, planets, or stars. The positions of these bodies may be calculated in a variety of coordinate systems ranging from barycentric rectangular coordinates to apparent geocentric coordinates. The latter, given as familiar right ascension and declination, will be of most interest to amateur observers, while the former will probably only interest researchers. The terminology used, such as barycentric rectangular coordinates, may cause some difficulty for the amateur who is simply trying to figure out which general direction to look in to see Mars. A glossary of technical terms reprinted from the 1987 *Astronomical Almanac* is present in the documentation, which can be ordered from the U.S. Government Printing Office.

Physical ephemeris of planet. Physical ephemerides refer to the physical appearance of the planet and the changes visible during the year. Thus in this section you will find information such as visual magnitude and disk diameter and phase, as well as rotation data such as the sub-Earth latitude and longitude.

Sidereal times. This choice is convenient because it allows you to calculate local sidereal time for your location without going through the simple but tedious calculations outlined in the *Astronomical Almanac*.

Catalog definition. This option allows you to switch between three auxiliary catalogs: the FK4 catalog of 1,536 stars, a catalog of 233 compact extragalactic radio sources, and the Messier catalog.

Rise, set, and transit times. If you're planning an observing session, this might be useful. True, this function is probably overkill for the purpose, but it's easy enough to use.

Navigational information. By entering your latitude and longitude, this section computes an altitude and azimuth for a designated object.

Daily configuration. All you need to do is enter the date and this section gives a summary of the most frequently used information on the Sun, Moon, and planets (except Pluto), such as right ascension, declination, and magnitude.

Set default date and coordinates. You probably want to come here first. Once the defaults are set, especially constants like your latitude and longitude, you won't have to repeatedly

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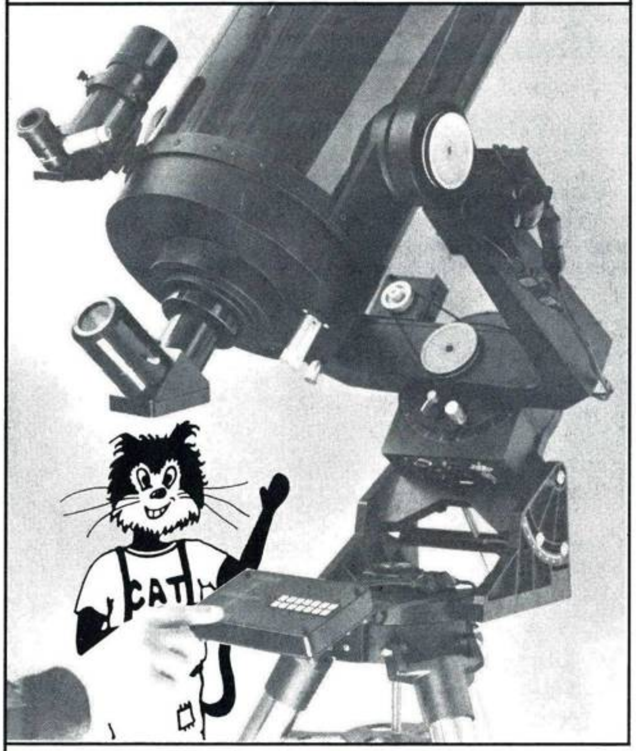

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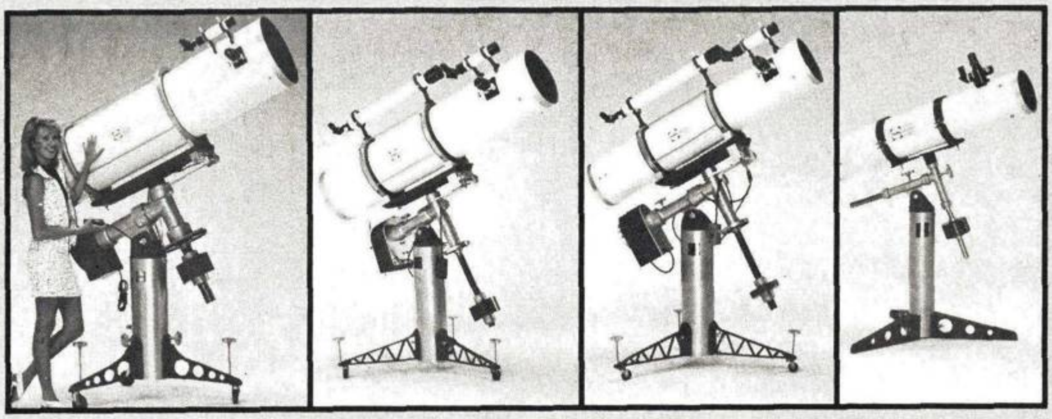

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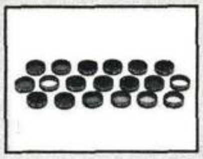

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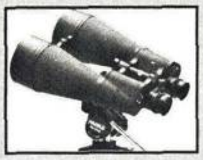

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type them in. Most software I use takes the default from the last value you entered. Not *The Floppy Almanac*. You must explicitly set the defaults by selecting this item from the main menu. Furthermore, the defaults are not remembered from one session to another. I hope the authors will consider improving the handling of defaults, especially because this would be so easy to do.

For the solar system the information is internally stored as a series of terms that are accurate only within a 400-day window. A much longer window could have been obtained but at the expense of increasing the number of terms in the series, thus lengthening the computation time. The choice made seems ideal because the results come out promptly, at least on my machine with an 8087 math chip.

The way time is handled is a major stumbling block in the easy use of *The Floppy Almanac*. This isn't surprising because it's also the major problem facing an amateur (and many professionals) trying to use the *Astronomical Almanac*. Although the independent argument for most tabulations is Terrestrial Dynamical Time (TDT), most of us probably have never heard of this relatively recent successor to ephemeris time.

According to the documentation, universal time differs from TDT by almost a minute. A table relating TDT and UT is available in the *Astronomical Almanac*. At the very least *The Floppy Almanac* should provide this table as a menu item. Even better would be building the table right into the time variable and allowing entries in either TDT or UT, depending on which is preferred. It's true that at the most accurate level, where milliseconds are important, not having this option is a problem since the TDT-UT difference can't be determined until after the fact. However, a real-time observer has to somehow cope with this small error source, so why not make it easier to handle by letting the computer give the most accurate answer available at the time of the observation?

Another problem with *The Floppy Almanac*'s use of time is that many of the tabulations have a column simply labeled "time" (not UT or TDT, just time). After realizing that in some tabulations time meant TDT and in others UT, I became leery of the simple label "time."

The bottom line is that you have to read the documentation very carefully to use *The Floppy Almanac* intelligently. I don't think this would be necessary if some effort were made to construct a more consistent user interface. This might make *The Floppy Almanac* deviate significantly from the *Astronomical Almanac*, but perhaps both approaches could be accommodated in the same program.

Overall I'm very pleased with *The Floppy Almanac*, though it could be improved if it were made more user friendly.

— Bruce L. Gotwols

A Tubular Planisphere

The Cosmic, an optical tube for learning and locating constellations, designed by Ariane and Bernard Vuarnesson, Sculptures-Jeux, Paris, France, distributed by SARUT Inc., 50 West 34th Street, New York, NY 10001, (1-800-345-0404), $25.

If you've ever used a kaleidoscope, then you know the principle behind the Cosmic, a device imported from France and used to learn the constellations in the Northern Hemisphere. Essentially the Cosmic does the job of a planisphere, except that the Cosmic displays the night sky in a tube that the user peers into at one end. The Cosmic can be adjusted hour by hour to any night of the year for observers between 30° and 60° north latitude. Horizon adaptors are supplied so the observer sees an accurate representation of the stars for his particular latitude. The tube depicts thirty-five stars and sixty constellations.

Positioned in one section of the two-inch-diameter tube is the semitransparent disk upon which the constellations are printed; a plastic magnifying lens in the other section enlarges the disk so the constellations fill the field of view when you look through the "eyepiece." Months and universal times are marked on the outside of the tube so the observer can adjust for time and date.

One problem with the design, however, is that if you want to use the Cosmic at night, you will have to illuminate the constellation disk with a red-lensed flashlight or depend on stray outdoor light to brighten the tube's interior. Otherwise, the use of this device is restricted to daytime or indoors, in which case it can at least show you what constellations will be visible for any night during the year. The consumer will have to judge for himself whether or not that makes the Cosmic worth the price, which is about four times that of a conventional planisphere.

— Jeff Kanipe

Biography and History

History of British Space Science by Harrie Massey and M. O. Robins, (Cambridge University Press, 1986), ISBN 0-521-30783-X, hardcover, 514 pages, $89.50.

Revolution in Science by I. Bernard Cohen, (Belknap Press of Harvard University Press, 1985), ISBN 0-674-76778-0, paperback, 711 pages, $9.95.

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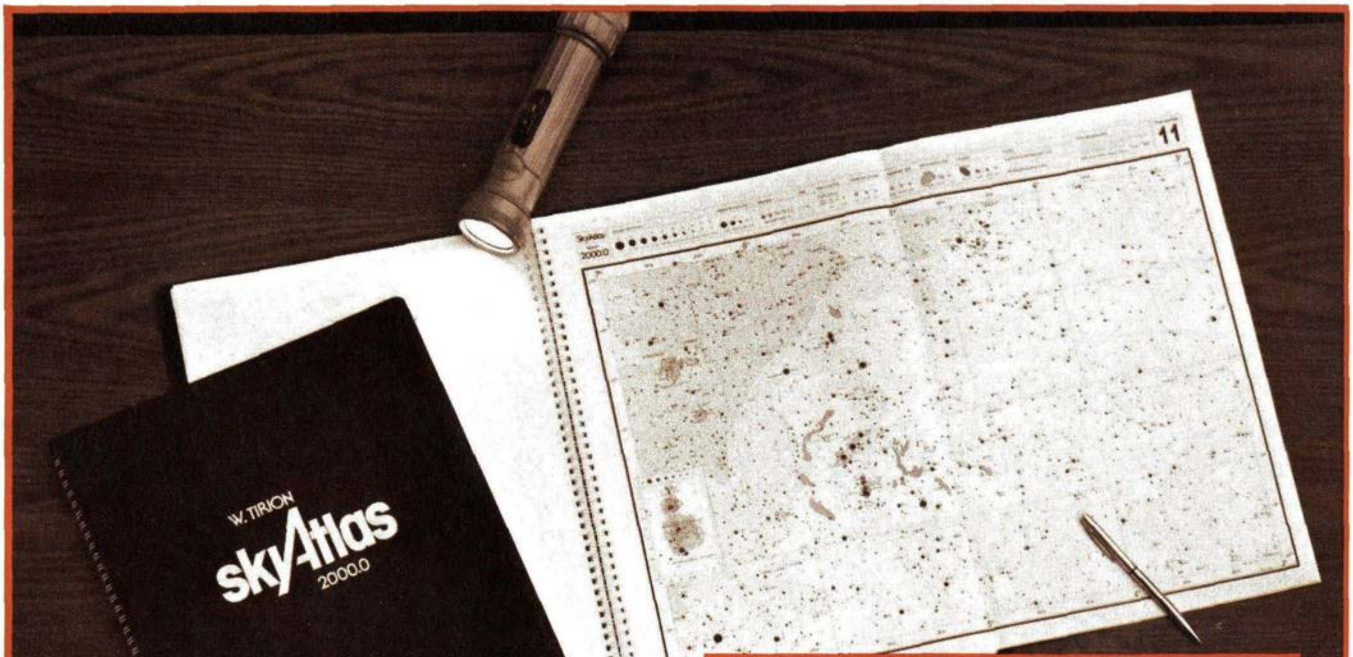
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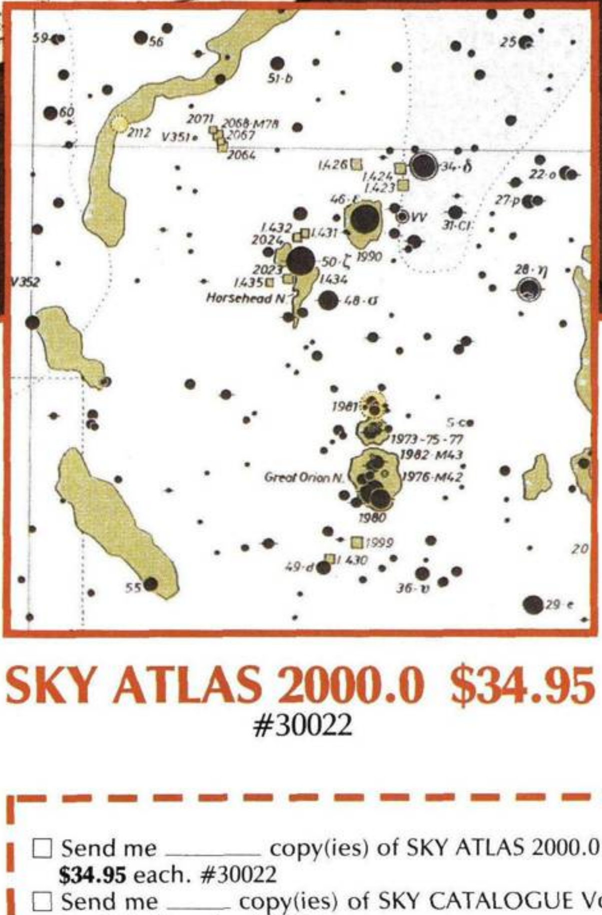
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2. Entries are limited to one per-person per-month. To be eligible for monthly prize awards, entries must be postmarked by the final day of the preceding month (i.e., November 30 for the December drawing). Monthly prizes will be selected in December 1987, January 1988, and February 1988. All entries must be postmarked by January 31, 1988. The grand prize will be awarded in February 1988. Monthly prize winners will become ineligible for future monthly awards, but will be eligible to win the grand prize. All entries qualified under these rules will be eligible for the grand prize.
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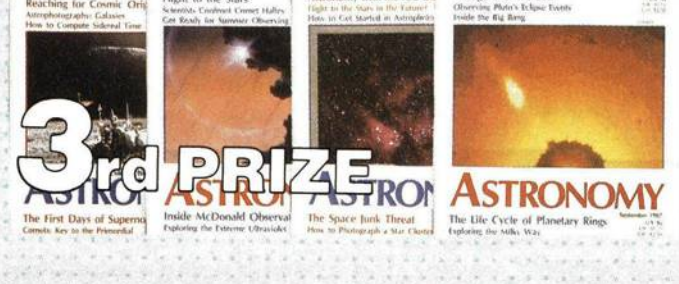
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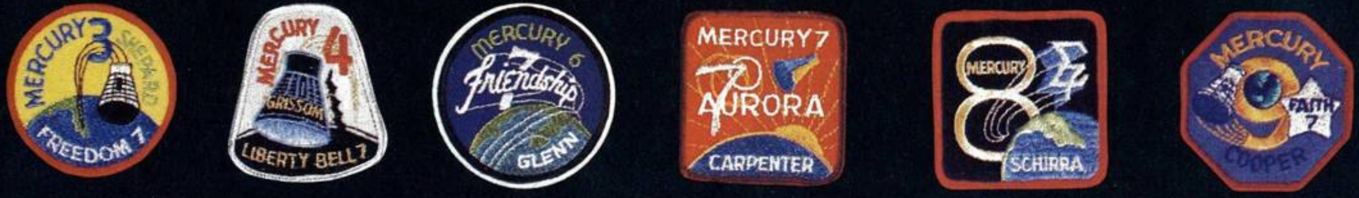
MERCURY 3 SHEPARD FREEDOM 7
MERCURY 4 GRISSOM LIBERTY BELL 7
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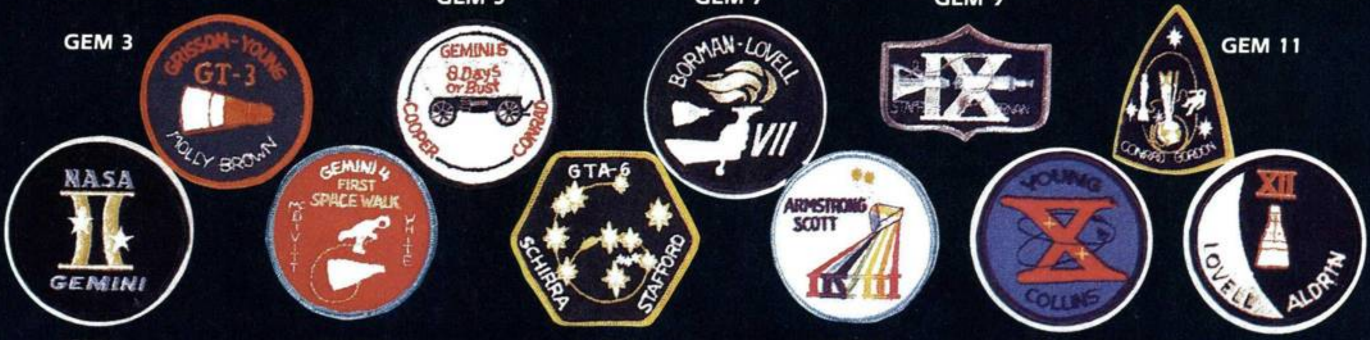
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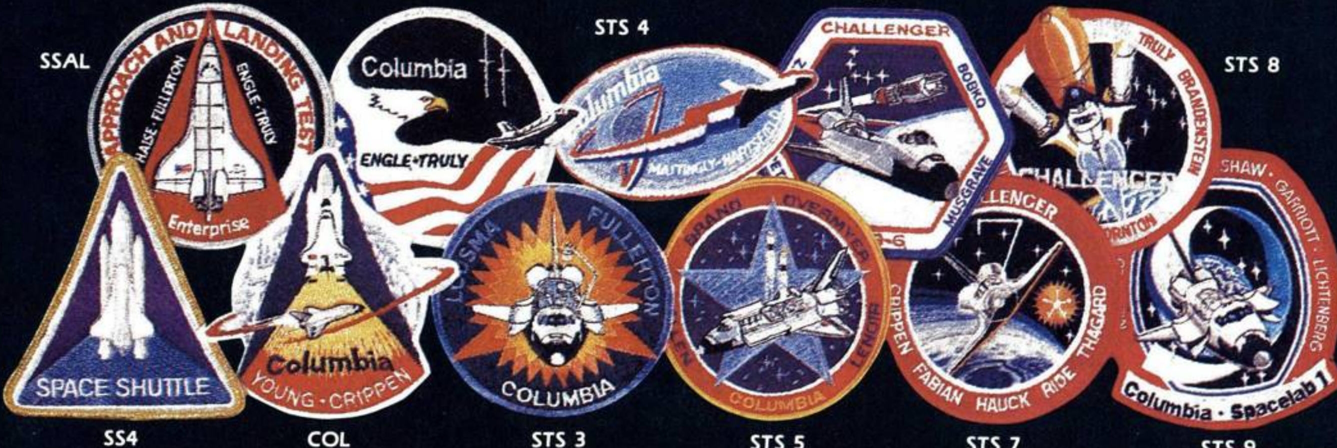
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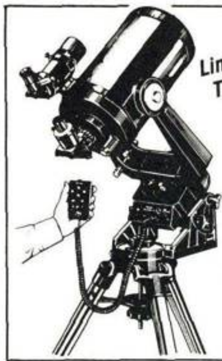

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10″ LX/5

2120 LX/5 *Included* accessories:

- Deluxe 1¼″/2″ star diagonal
- 9x60 quick-release illuminated finder
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- Hand control w/focus buttons
- New MCOG coatings & more!

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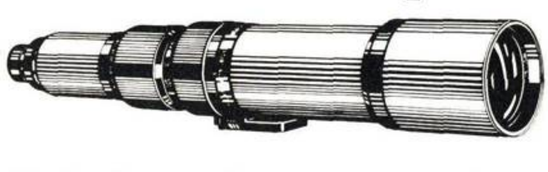
2080 LX/5 8″ $1789

15 to 60x Zoom Spotter!



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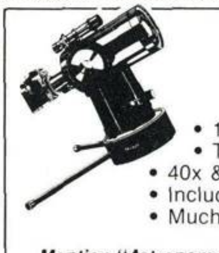

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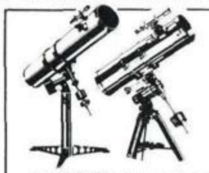

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97ER w/2 eyepieces, alum. case	399
291 60mm Eq Refractor	299
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Nebula 908 (1¼″)	69
Nebula 911 (rear cell)	119
Off-axis guider w/ill ret	169
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Star diagonal—2″	199
Tele-extender	37
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Weight set 1401 (2080)	94
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Partial listing only, please call for any item not listed!

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Super Wide Angle 13.8mm	139
Super Wide Angle 18mm	159
Super Wide Angle 24.5mm	169
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Super Wide Angle 40mm	309
Ultra Wide Angle 4.7mm	169
Ultra Wide Angle 6.7mm	199
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A $1300 2045 for $479!

2045: Do-it-all performer in a compact package. An astronomical scope, spotting scope, and telephoto lens -- all in one! Take your pick of a first-line scope or one with a minor cosmetic blemish. You probably won't be able to find the blemish (Meade's Q.C. people are so fussy they'll reject scopes for tiny flaws that other manufacturers' don't even notice), and Meade guarantees that even the blemished scopes will meet every published optical and mechanical specification perfectly. Blemished or unblemished, you save a bundle! Complete with all these features: 4" 1000mm f/10 optical tube; dust cover, 5 x 24mm finderscope; 1 1/4" star diagonal/visual back; 1 1/4" 25mm (40x) and 9mm (111x) modified achromatic eyepieces; dual arm fork mount; AC drive motor; manual slow motion controls on both axes; setting circles (r. a. circle power driven); tabletop tripod; metal-clad carrying case; lifetime warranty. *$1300 list.* Regularly $595.
First line 2045, only $499! Cosmetically blemished but fully-warranteed 2045, only $479!

A $3220 2080/LX3 for $1369!

2080/LX3: We bought the 2080 inventories of several smaller dealers -- and the special price concessions we got make this the best value in 8" Schmidt-Cassegrain telescopes available today. Complete and ready to use the minute you get it, with all these features and accessories: 8" 2000mm f/10 optical tube; multi-coated silver optics for 23% higher light transmission and increased contrast; metal dust cover; 8 x 50mm right angle finderscope with illuminated polar axis reticle (includes battery); piggyback camera mount; 1 1/4" multicoated star diagonal; 1 1/4" visual back; 1 1/4" 26mm (77x) and 9.7mm (206x) Super Plossl eyepieces (some may have 1 1/4" 100x 20mm Research Erfle and 286x 7mm Research Ortho eyepieces); fork mount; LX precision worm gear drive; quartz-controlled sidereal rate electronic drive with power adapters and 25' extension cords for AC and 12 volt DC operation; manual slow motion controls and locks on both axes; r. a. and declination setting circles (r. a. circle power driven); power panel with input/output connections for optional hand control, map light, illuminated reticle eyepiece, and declination motor; equatorial wedge with compass, latitude scale, bubble level, micrometric azimuth control, deluxe latitude adjuster, and no-tool knob set; adjustable height tripod; audio instruction cassette; foam-lined carrying case with lock; lifetime warranty. *$3220 list.* Formerly $1699.
Brand-new first-line 2080/LX3, with MCSO, $1369!

CREDIT CARD SALES

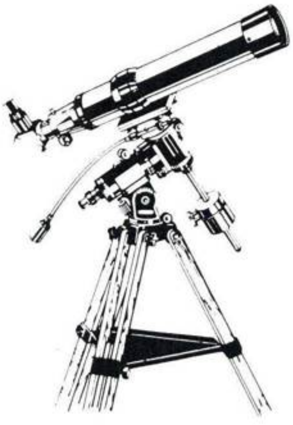
Sorry, but these special prices are so low that if you use a credit card to buy one of these special price telescopes, we must add a small surcharge to the low cash prices shown to cover the fees charged us by the credit card companies for accepting your card. Add 2% to the prices shown if you use Mastercard, Visa, or Discover. Add 4% if you use American Express. Insured UPS shipping is still free to all 48 continental United States, and the prices shown are your total delivered cost if you pay by check or money order.

A $3600 2080/LX5 for $1699!

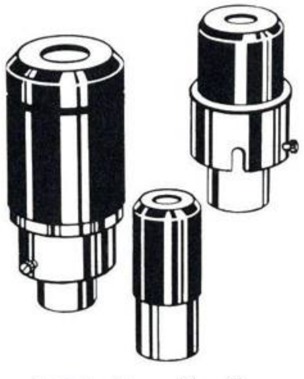
2080/LX5: Here's a superb buy on a superb 8" telescope -- the state-of-the-art Meade 2080/LX5. You'll save better than 52% off the list price thanks to our large-volume buying power. This special extra-discount price is good from now through December 31 only, so don't miss this once-in-a-lifetime savings! Complete with all these features and accessories: 8" 2000mm f/10 optical tube; multi-coated optics group for 20% higher light transmission and increased contrast; metal dust cover; 9 x 60mm right angle finderscope with illuminated polar axis reticle (includes battery); 1/10th wave 2" multicoated star diagonal with 1 1/4" eyepiece adapter; 1 1/4" 26mm (77x) Super Plossl eyepiece; fork mount; LX precision worm gear drive; quartz-controlled sidereal rate electronic drive with power adapters and 25' extension cords for AC and 12 volt DC operation, plus battery pack for penlight battery operation away from all power sources; hand control with built-in map light, control for optional electric focuser, pushbutton controls for 2x drive corrector and 8x image scanning functions, switch-selected quartz/manual control and northern/southern hemisphere operation, variable rate control; manual slow motion controls and locks on both axes; r. a. and declination setting circles (r. a. circle power driven); power panel with input/output connections for optional illuminated reticle eyepiece, electric focuser, and declination motor; equatorial wedge with compass, latitude scale, bubble level, micrometric azimuth control, deluxe latitude adjuster, and no-tool knob set; adjustable height tripod; audio instruction cassette; foam-lined carrying case with lock; lifetime warranty. *$3600 list.* Regularly $1799.
Brand-new first-line 2080/LX5, with MCOG, $1699!

Premium TeleVue eyepieces at low, low prices!

A telescope can only look as good as the eyepiece you use with it -- so it makes sense to use exceptional eyepieces to get the most from top quality telescopes like the ones on these pages. TeleVue eyepieces ***are*** exceptional. They can make any telescope look its very best. And our freight-paid TeleVue eyepiece prices -- unchanged since 9/1 of *1986* -- make these superb eyepieces look even better! From the premium Plossls that started the revolution in quality eyepieces, to the 65° field of the fabulous Wide Fields, to the stunning 82° field of the Naglers -- we have them all! Money-saving low prices on TeleVue telescopes, too!



1 1/4" Plossls (7.4, 10.5, 13, 17, 21, or 26mm), *$115 list*	$82.50
1 1/4" Plossls (32 or 40mm), *$135 list*	$97.50
2" 55mm Plossl, *$230 list*	$164.50
1 1/4" 4.8mm Nagler, *$190 list*	$134.50
1 1/4" 7mm Nagler, *$235 list*	$167.50
1 1/4"/2" 9mm Nagler, *$275 list*	$194.50
1 1/4"/2" 11mm Nagler, *$295 list*	$204.50
1 1/4"/2" 12mm Nagler II, *$325 list*	$234.50
1 1/4"/2" 13mm Nagler, *$310 list*	$217.50
1 1/4"/2" 16mm Nagler II, *$370 list*	$269.50
2" 20mm Nagler II, *$450 list*	$299.50
1 1/4" 15mm Wide Field, *$165 list*	$114.50
1 1/4" 19mm Wide Field, *$185 list*	$129.50
1 1/4" 24mm Wide Field, *$205 list*	$144.50
2" 32mm Wide Field, *$290 list*	$199.50
2" 40mm Wide Field, *$360 list*	$249.50
Oracle 3" apochromat, *$995 list*	$699.00
Renaissance 4" semi-apochromat, *$1995 list*	$1495.00
Renaissance, on aluminum equatorial mount, *$2775 list*	$2095.00



Tele Vue

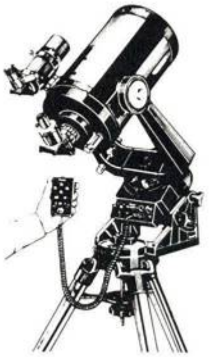
Meade Sale! (cont.)

We made some special purchases on over $500,000.00 worth of the best telescopes, binoculars, and eyepieces that Meade Instruments has to offer -- and we're still pricing them to save you as much as 66% off the list price! Quantities are limited, however, and these prices are good only through December 31, so don't miss out. If you want to give yourself a Christmas present that will give you a lifetime of observing pleasure -- and you want to save big money doing it -- there's never been a better time than right now at Ad-Libs Astronomics!

A $5400 2120/LX3 for $1799!

2120/LX3: Meade has made a special final production run on this superlative 10" Schmidt-Cassegrain telescope -- and only 250 people will be able to make the 10" telescope buy of a lifetime! You save 2/3! It's complete with all these features and accessories: 10" 2500mm f/10 optical tube; multi-coated silver optics for 23% higher light transmission and increased contrast; metal dust cover; 8 x 50mm right angle finder with illuminated polar axis reticle (includes battery); piggyback camera mount; 1 1/4" multicoated star diagonal; 1 1/4" visual back; 1 1/4" 22mm (113x) Super Plossl eyepiece; fork mount; LX precision worm gear drive; quartz-controlled sidereal rate electronic drive with power adapters and 25' extension cords for AC and 12 volt DC operation; bonus #36 hand control; manual slow motion controls and locks on both axes; r. a. and declination setting circles (r. a. circle power driven); power panel with input/output connections for optional map light, illuminated reticle eyepiece, and declination motor; equatorial wedge with compass, latitude scale, bubble level, micrometric azimuth control, deluxe latitude adjuster, and no-tool knob set; adjustable height tripod; audio instruction cassette; foam-lined carrying case with lock; lifetime warranty. *$5400 list.* Formerly a $2509 package. **2120/LX3, with MCSO and #36 hand control, $1799!**

A $5200 2120/LX5 for $1999!



2120/LX5: Here's a sensational limited time savings of over $3200 on the premier 10" telescope in the entire world -- the very newest Meade 2120/LX5. That's better than 61% off the list price! This special sale positively ends December 31, so don't miss this once-in-a-lifetime opportunity! Complete with all these features: 10" 2500mm f/10 optical tube that gathers 57% more light than an 8" scope; multi-coated optics group for 20% higher light transmission and increased contrast; metal dust cover; 9 x 60mm right angle finderscope with illuminated polar axis reticle (includes battery); 1/10th wave 2" multicoated star diagonal with 1 1/4" eyepiece adapter; 1 1/4" 26mm (96x) Super Plossl eyepiece; fork mount; LX precision worm gear drive; quartz-controlled sidereal rate electronic drive with power adapters and 25' extension cords for AC and 12 volt DC operation, plus battery pack for penlight battery operation away from all power sources; hand control with built-in map light, control for optional electric focuser, pushbutton controls for 2x drive corrector and 8x image scanning functions, switch-selected quartz/manual control and northern/southern hemisphere operation, variable rate control; manual slow motion controls and locks on both axes; r. a. and declination setting circles (r. a. circle power driven); power panel with input/output connections for optional illuminated reticle eyepiece, electric focuser, and declination motor; equatorial wedge with compass, latitude scale, bubble level, micrometric azimuth control, deluxe latitude adjuster, and no-tool knob set; adjustable height tripod; audio instruction cassette; foam-lined carrying case with lock; lifetime warranty. *$5200 list.* Regularly $2699. **2120/LX5, with MCOG, $1999!**

A $1400 6600 reflector for $499!

6600: Perhaps the ideal combination of size, performance, and price, a 6" f/5 Newtonian reflector like the Meade 6600 may well be all the telescope you'll ever need. Compact and easily transportable, the 6600 weighs only 44 lbs. Photography is easily accomplished by adding an optional camera adapter and electric drive/drive corrector. Take your pick of a first-line scope or one with a cosmetic blemish or two so minor you probably won't even be able to find them. Every scope, blemished or first line, is fully guaranteed by Meade to meet every published optical and mechanical specification perfectly. Blemished or unblemished, you save a bundle! Complete with all these features: 6" 765mm f/5 optical tube; dust cover; 6 x 30 finderscope; 1 1/4" focuser; 1 1/4" 25mm (31x) and 9mm (85x) modified achromatic eyepieces; German equatorial mount with setting circles and manual slow motion controls; adjustable wood tripod with accessory tray; lifetime warranty. *$1400 list.* Regularly $699.

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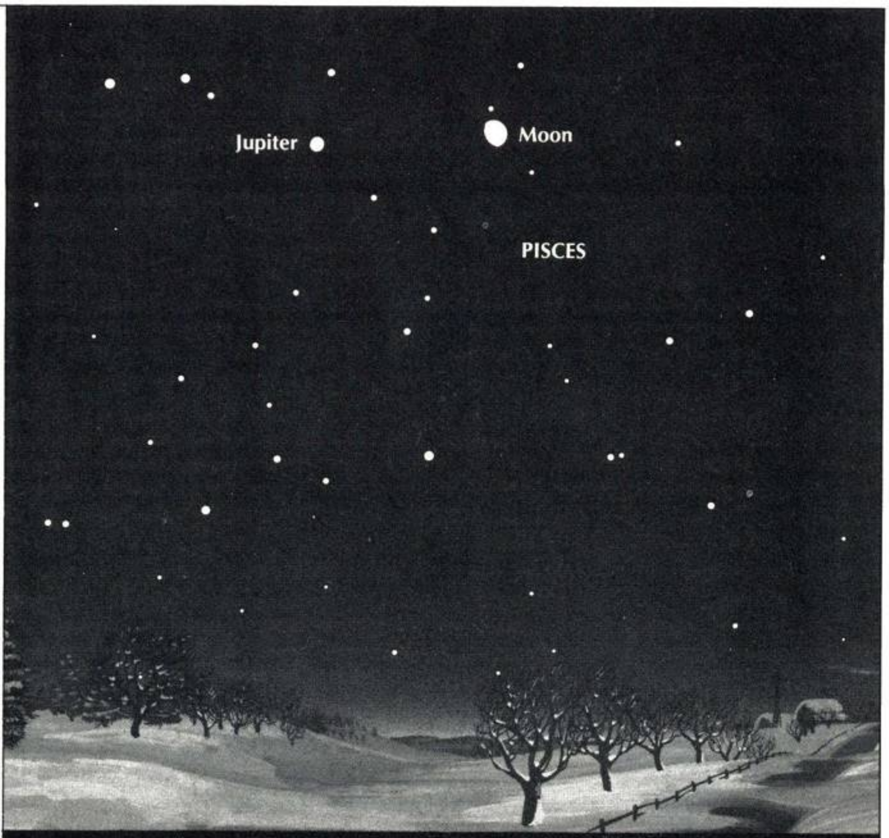
Eye on the Sky

December's Geminid Meteors

by Robert Burnham



Looking southeast, December 1, evening twilight

The Wanderers

As 1987 ends, two "wanderers" are prominent in the evening sky. Look toward the southwest to see **Venus** gleaming through leafless branches. Because Venus's brightness is −4.0 magnitude, many people unaware of celestial objects will simply take Venus for an airplane with landing lights on.

Venus is coasting slowly eastward through Sagittarius, but this summertime constellation lies too low in the twilight to be seen. Venus slowly gained elevation during the autumn months, but between now and April Venus will climb much higher to become the most conspicuous object in the evening sky aside from the Moon.

Though it is not as bright as Venus, no one would call **Jupiter**, the other planet in the evening sky, inconspicuous. In fact, if Venus is temporarily blocked or obscured by a small cloud or nearby rooftop, Jupiter will be the sole planetary "star" visible. At nightfall it stands east of due south and roughly halfway between the horizon and overhead. Two months ago Jupiter was at opposition when, relative to our vantage point, the planet lay opposite the Sun in the sky. At that time Jupiter was nearest Earth and shone at magnitude −2.9, its brightest in twelve years. Jupiter is still quite a luminary at magnitude −2.7.

At present Jupiter lies nearly stationary among the stars of Pisces, but Jupiter's movement would be hard to detect anyway, because Pisces lacks bright stars to gauge the progress of Jupiter with.

Venus sets by 7 p.m., leaving the sky to Jupiter, which sets around 3 a.m. At 5 a.m. when the sky is still fully dark and with spring's constellations in full array, **Mars** climbs into view in the southeast. You'll probably see the 1st-magnitude white star Spica (in Virgo) at first; amber-tinted Mars lies below it and shines perceptibly dimmer at magnitude 1.7.

Mars is slipping eastward out of Virgo and into Libra, a faint constellation that offers few stars to track the movement of Mars by. Mars may not appear to move very quickly, but its orbital motion is nonetheless swift enough so Earth won't overtake it until late next September.

During the first week of December **Mercury** is visible far below and to the left of Mars as morning twilight starts. Unfortunately Mercury lies very low, roughly 3° high (half a binocular field of view) on December 1, forty-five minutes before sunrise. To see Mercury, you need a flat unobstructed horizon toward the east-southeast; any haze will most likely hide the planet. Mercury looks reddish white and its magnitude is −0.7. (Remember that twilight makes objects look somewhat dimmer, however.) After the first week of the month Mercury lies too low to be seen; it meets the Sun at superior conjunction on December 23.

On the night of December 3 to 4, a nearly Full Moon glides through the **Pleiades star cluster** in Taurus, covering in succession many of the Pleiades' members. Because the Moon is so bright, you'll need binoculars or a small telescope to follow a star right up to its disappearance. For viewers on the West Coast the event occurs around midnight (as December 3 becomes the 4th); on the East Coast it is visible around 3 a.m. on the 4th.

December's best meteor shower is the **Geminids**, which reaches peak activity in the early morning hours of the 14th. The Geminids come from a burnt-out comet; the nucleus of this comet (still orbiting the Sun) is called 1983 TB. Although the shower is richer than August's Perseids, the Last Quarter Moon that rises around midnight impedes anyone trying camera-on-tripod meteor photos.

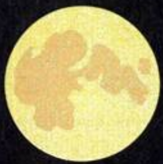
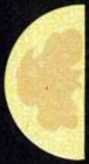
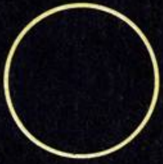
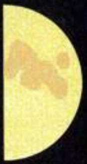
The Geminids are bright and moderately fast, though not as swift as last month's Leonids. Most appear white or yellow, but other colors have been seen. Under a dark sky you'll spot about one Geminid a minute coming from near Castor.

The 31st is the legal end of the calendar year, but in astronomical terms the end of the year is the **solstice**, the moment when the Sun reaches its greatest distance south in the sky and winter begins. (This year, the solstice is December 22 at 4:46 a.m. EST.) Though the coldest months still lie ahead because of the lag of Earth's weather systems, the Sun now begins to

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Opposite page: The city of Hilo, Hawaii, and its harbor glitter like jewels beneath an opening in the cloud deck as the Full Moon rises over the scene. The star above the Moon is Spica. Photo by William D. Heacox.

December Night Sky

Full Moon	Last Quarter	New Moon	First Quarter
December 5	December 13	December 20	December 27
3:01 a.m. EST	6:41 a.m. EST	1:25 p.m. EST	5:01 p.m. EST

1st The Moon lies to the upper right of Jupiter in the evening sky (see diagram on page 58).

2nd Venus is at its greatest orbital distance from the Sun.

3rd The Moon passes through the Pleiades star cluster (see text for times).

5th Full Moon is at 3:01 a.m. EST.

10th The Moon is farthest from Earth at 9:09 a.m. EST: 251,728 miles (405,117 kilometers).

13th Last Quarter Moon occurs at 6:41 a.m. EST.

14th The Geminid meteor shower is at peak activity in the early morning hours.

15th Saturn is in conjunction with the Sun.

18th Mercury is at its greatest orbital distance from the Sun.

19th Uranus is in conjunction with the Sun.

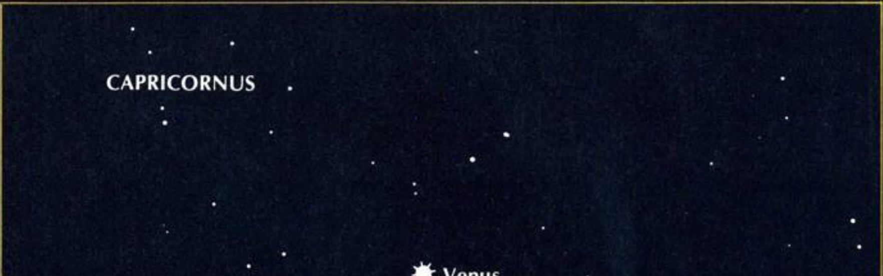
20th The Moon is New at 1:25 p.m. EST.

22nd The Sun reaches its most southerly declination at 4:46 a.m. EST, which signals the start of winter in the Northern Hemisphere. The Moon is closest to Earth at 6:12 a.m. EST: 224,476 miles (361,259 kilometers); it lies to the lower left of Venus in the evening sky (see below).

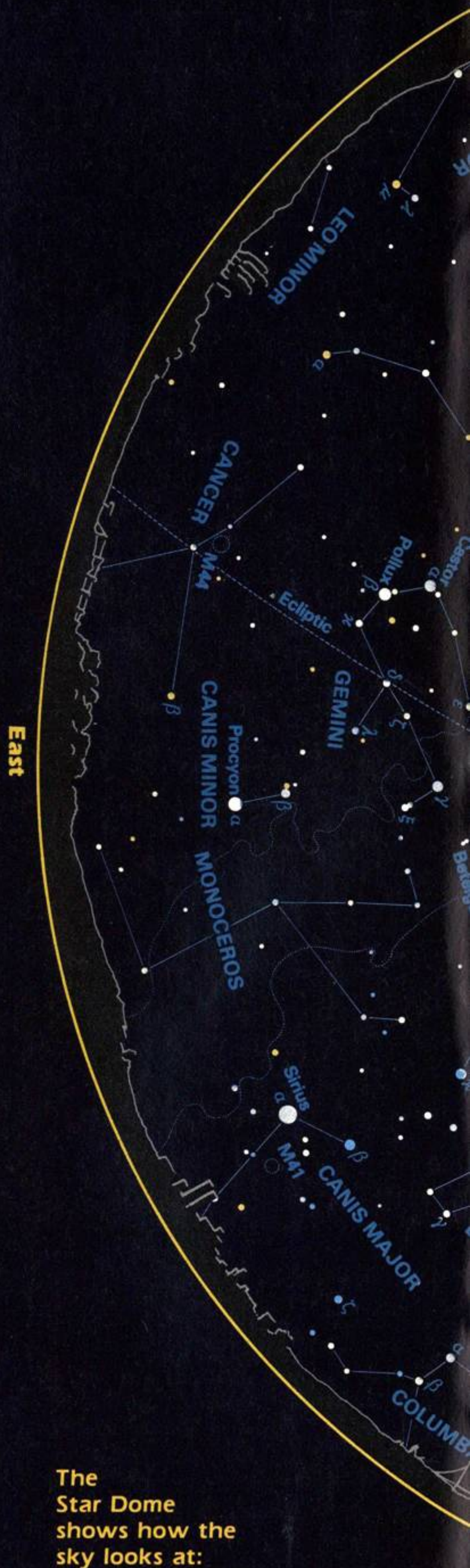
23rd Mercury is in superior conjunction with the Sun.

27th First Quarter Moon is at 5:01 p.m. EST.

29th Neptune is in conjunction with the Sun.

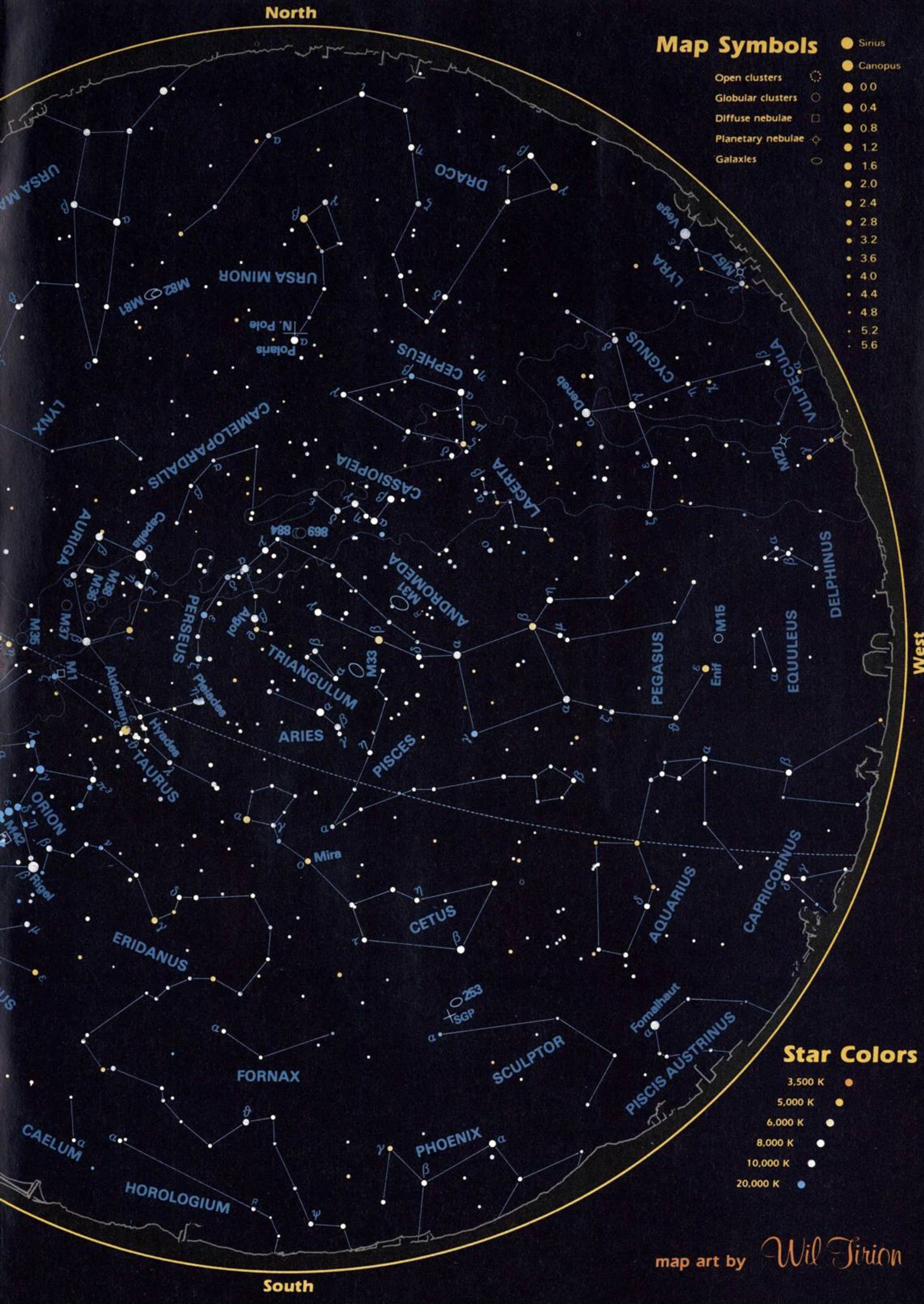


Looking southwest, December 22, evening twilight



The Star Dome shows how the sky looks at:

9:30 p.m. on December 1
8:30 p.m. on December 15
7:30 p.m. on December 31


North
South
West
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
URSA MA
DRACO
URSA MINOR
M82
M81
N. Pole
Polaris
LYRA
Vega
M57
CYGNUS
Deneb
VULPECULA
M27
CEPHEUS
LYNX
CAMELOPARDALIS
CASSIOPEIA
LACERTA
DELPHINUS
AURIGA
Capella
869
884
ANDROMEDA
M31
M38
M36
M37
M35
PERSEUS
Algol
TRIANGULUM
M33
PEGASUS
M15
Enif
EQUULEUS
M1
Aldebaran
Hyades
Pleiades
TAURUS
ARIES
PISCES
ORION
M42
Rigel
Mira
CETUS
AQUARIUS
CAPRICORNUS
ERIDANUS
253
SGP
Fomalhaut
PISCIS AUSTRINUS
SCULPTOR
FORNAX
CAELUM
PHOENIX
HOROLOGIUM
US

map art by Wil Tirion

gradually make its way north again toward the vernal equinox in March.

The Starry Sky

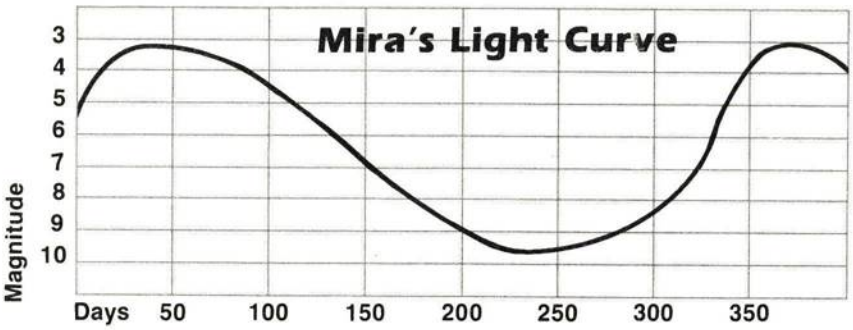
When the high Full Moon of the winter solstice pours its light on the land, the night is very beautiful. But all that light washes out the stars. So set aside a clear, moonless evening soon after the middle of the month to escape into the country for some real stargazing.

Glance in the southeast around 8 or 9 p.m. to find the tall, familiar figure of **Orion** the Hunter striding upward. Ruddy Betelgeuse marks one shoulder, while Rigel is the opposite knee. Cinched tight by his three-starred belt, Orion holds a lionskin shield toward **Taurus** the Bull, which has its triangular face in the Hyades cluster. The Bull's horns point eastward in a "V". (The Pleiades form the Bull's shoulder.) Aldebaran, the Bull's eye, is an orange star that is not a physical member of the Hyades cluster; it lies about halfway between us and the Hyades.

Engaged with Taurus, Orion doesn't notice the Hare **Lepus**, a small boxlike pattern of stars with outlying "ears" below his feet. Likewise, Orion's Hound **Canis Major**, poking over the horizon with bright Sirius, is too occupied to spot the bunny. Orion stands on the bank of the River **Eridanus**, a faint string of stars that begins next to Rigel and meanders south over the horizon.

One of Taurus' horns is poking **Auriga** the Charioteer, a large pentagonal figure that includes bright yellowish Capella and a sprinkle of Milky Way stars for binoculars. The other horn points to **Gemini** the Twins, two parallel lines of stars that run back toward Orion from Castor and Pollux.

The stars of late autumn scatter across the southwestern sky. Following the ecliptic (or zodiac) westward from Taurus, you pass dim **Aries** the Ram to reach **Pisces** the Fishes. Pisces dwarfs Aries, but Pisces is equally dim except for its present planet-guest Jupiter. Below Pisces swims **Cetus** the Whale; its famed variable star Mira may be shining fainter than the map shows (see Skylore).



On from Pisces, the ecliptic runs down to the western horizon through **Aquarius** the Water-Carrier, a figure that's hard to trace even under a dark sky. Facing west, you'll see a large square standing on one corner to the upper right of Aquarius. This is **Pegasus** the Flying Horse of Perseus. (If you have binoculars or a telescope, locate the star Enif in Pegasus and look to its lower right for M-15, a nice globular cluster.)

The upper point of the square is a star called Alpheratz, which actually belongs to **Andromeda** the Chained Maiden. This constellation is a narrow "V" that points overhead. Locate brightish Beta (β), and from there look for galaxies M-31 (visible with the naked eye under good skies) and M-33 (in **Triangulum** the Triangle and more difficult to spot).

Andromeda's Hero **Perseus** stands next to her, a wishbone of stars with one branch running south to the Pleiades. Her mother, Queen **Cassiopeia**, is a wide "M" that lies well above Polaris, the pole star, when you face north. Andromeda's father, King **Cepheus**, is a distorted pentagon standing (this month) to Polaris' left.

It's appropriate to finish this month by saying goodbye to the last vestige of summer — **Cygnus** the Swan. It lies between Cepheus and Enif in Pegasus below the wriggle of stars marking **Lacerta** the Lizard. The brightest star of Cygnus is Deneb, a stellar beacon you won't see again in the evening until 1988 reaches solar noon at the summer solstice next June.

Skylore

Anyone casually looking at the sky might believe the brightness of the stars never changes. Yet it appears the ancients knew the brightness of at least a few stars did change, for they gave their stars names that hinted at unusual behavior. For example, the star Beta in Perseus normally shines at magnitude 2.2. But every 2 days and 21 hours it drops down to magnitude 3.4, and then its brightness rises again, all in about 15 hours. Although Beta's variability wasn't officially discovered until 1667, the ancients obviously knew something was going on because they called the star Algol, corrupt Arabic for "the Demon."

Once you know to look for it, the brightness change is relatively easy to see. But Algol's changes must have been hard to discover because the range is only a little more than one magnitude. It's puzzling therefore that Algol should have been found out, while a variable star in the tail of Cetus wasn't discovered until the Renaissance — despite a *six-magnitude* range.

Today this latter star is called Mira, Latin for "the Wonderful." Over a period of some 332 days Mira ranges in brightness from a minimum of roughly 9th magnitude to a maximum of about 3rd. It was first seen by Dutch astronomer/clergyman David Fabricius, who observed it at 3rd magnitude in August 1596. A few months later it was no longer visible, and Fabricius could find no record of the star on any astronomical charts or globes.

Unaware of Fabricius' observations, celestial cartographer Johann Bayer included the star in his 1603 *Uranometria*, plotting it at 4th magnitude and labeling it Omicron. Although Fabricius again noted the star at 3rd magnitude in February 1609, it wasn't until 1638 that another Dutch astronomer, Phocylides Holwarda, established that its brightness varied in a regular manner. Finally, writing about the star in 1662, Johannes Hevelius gave it the name it is now known by.

Today astronomers know Mira as the prototype of a large class of stars called long-period variables. These are reddish stars about as massive as the Sun that slowly pulsate like a giant heart. As a Mira-type star grows in size, it cools and fades; thus Mira is brightest when smallest. Yet even at minimum size Mira is so large that if it replaced the Sun, Earth would lie well within the star's outer layers!

A stage of pulsating variability like Mira's probably awaits every star that has about the same mass as the Sun. After millions of years as a Mira variable, during which much of the star's material is driven off into space, these stars evolve into white dwarfs — tiny white-hot stellar remnants.

Mira is especially interesting this month because it reaches maximum brightness early in January. Once or twice a week look for Mira where the map indicates, and if Mira is visible, compare its brightness to that of other stars nearby. Can you detect the date when Mira is brightest? How bright does it get? And how far into the new year can you keep it in view?

Opposite page, top: From the 14,000-foot summit of Mauna Kea in Hawaii, astronomer William D. Heacox photographed the Full Moon rising in the shadow of the extinct volcano. The Moon was just emerging from the April 14, 1987, penumbral eclipse visible from the continental United States. This photo and the one on page 59 were taken during an undergraduate astronomy program field trip of the University of Hawaii at Hilo. Heacox used Kodachrome 64 film and a 70mm lens.

Opposite page, bottom: Moonlight refracted by high ice clouds created this colorful halo over Miami, Florida, in August 1985. Jupiter is at upper left. Photo by David Rights.

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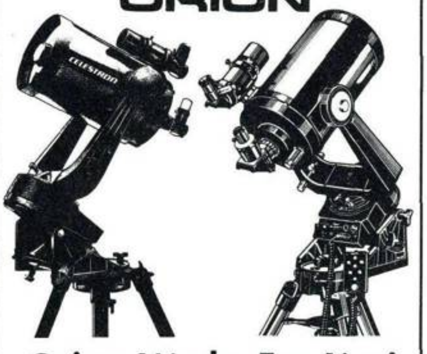

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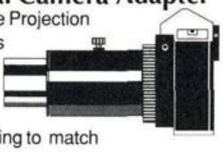

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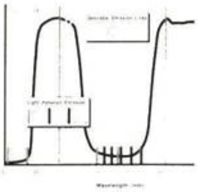

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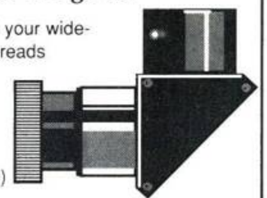

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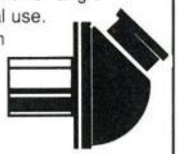

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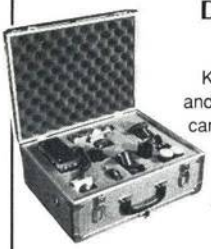

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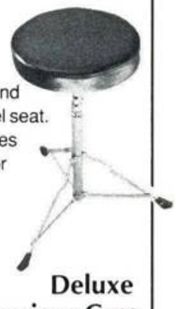
#5921 (19 1/2"x12"x6 1/2")
$59.95 (4.95)

Observer's Chair



Perfect for all types of telescopic viewing. It has six adjustable height positions from 19" to 24" and a very comfortable padded swivel seat. The legs fold and the seat removes from the chrome-plated frame, for easy storage. Comfortable and very affordable. Try it!

#5935 **$36.95** (3.50)

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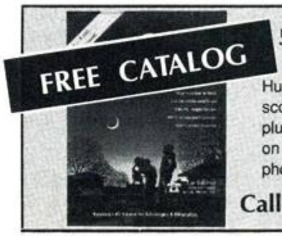
#5913 **$17.95** (1.95)



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Equipment
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The ATI "CAT": The Wave of the Future?

As you read this, a revolution is taking place. Computer-based finding devices for Schmidt-Cassegrain telescopes are changing the way backyard astronomy is done. These devices, now entering the market, allow observers to quickly find hundreds of deep-sky objects by drawing on internal databases complete with the positions, magnitudes, and sizes of objects. Because these finding devices could radically change the way backyard astronomers view the universe, ASTRONOMY put the first mass-marketed computer-aided finding device through its paces.

ATI CAT
Advanced Technology Instruments
P.O. Box 246
Carmel Valley, CA 93924
(408) 659-0437
Designer: Mike Simmons
List Price: $1,995
Requires: A Celestron International C8 or C11 or Meade Instruments 2080 or 2120 Schmidt-Cassegrain telescope for standard by-the-book installation and operation. Custom installation on other telescopes is possible; consult the manufacturer.
What Does It Do? The ATI CAT is a computer-based locating device that, once installed and calibrated, enables users of Schmidt-Cassegrain telescopes to locate 7,840 deep-sky objects and 351 stars. The device does not *drive* the telescope, but an illuminated control console shows users precisely where to aim the telescope by hand. The built-in database contains modern, high-quality information on objects and works with epoch 1988.0 coordinates.

Computer-based finding devices allow observers to quickly find deep-sky objects by drawing on databases of positions, magnitudes, and sizes of objects.

The Advanced Technology Instruments "CAT" (Computer-Aided Telescope) consists of a computer and two encoders that fit onto Schmidt-Cassegrain telescopes and enable the computer software to "find" objects stored in its database. The device does not move the telescope, but it tells you when you have moved the telescope to the right spot for a given object. At present the ATI CAT fits onto 8-inch and 11-inch telescopes made by Celestron International and 8-inch and 10-inch telescopes produced by Meade Instruments Corp. With special instructions from ATI, the device can also be adapted to other telescopes.

ATI, the small company in Carmel Valley, California, that produces the CAT, was founded by Bob Bogardus, an amateur astronomer who wanted to see technology catch up with deep-sky observing. The CAT was designed by Mike Simmons, a computer expert and telescope builder who also designed a computer-driven telescope device for the California-based firm Celestron International.

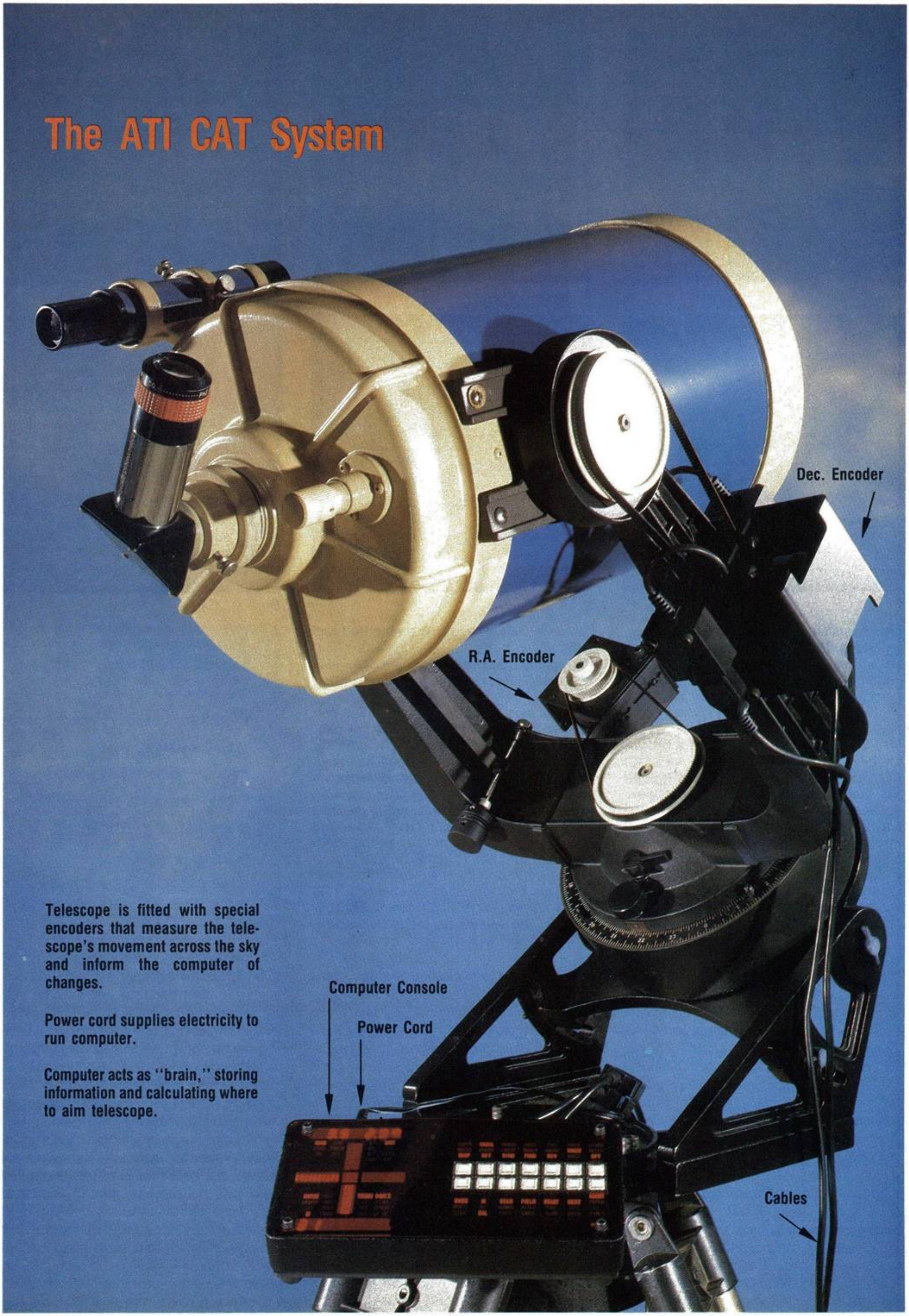
The miniature suitcase that protects the CAT measures 15" by 11.5" by 5.5". It contains a control console (which contains the computer electronics), right ascension and declination encoders, an encoder cable, a power cable that can connect to a 9-volt battery or 12-volt car battery, a 120-volt AC to 12 volt DC power supply, a user's manual, and a manual with hardcopy versions of the *Computerized New General Catalogue* (*CNGC*) and a database of 351 stars. The unit is packaged elaborately: twill pouches hold the console and cables, and the plastic-coated pages of the instruction manual will survive many damp nights of observing.

The brain of the CAT is the control console, an 8" by 4" by 1" rectangular box with a fourteen-key keypad; over a hundred red-backlit displays; a "red cross" of light-emitting diodes (LEDs); digital readouts for right ascension, declination, and object information; and the computer's database, digitally stored in integrated circuits.

The console fits onto the base of the wedges supplied with telescopes made by Celestron International and Meade Instruments Corp. With the keypad you input instructions into the computer to initialize the unit to work at a specific observing site and time. To select the objects you want to find, you input the numbers of the objects on the keypad. The red cross has four error bars made of tiny rectangular LEDs that show for both directions on both axes how far away the telescope is point-

The Computer-Aided Telescope from Advanced Technology Instruments installed on a refinished 8-inch Schmidt-Cassegrain telescope manufactured by Celestron International. Because it enables amateur astronomers to find any of several thousand sky objects quickly, the ATI CAT and similar devices now on the market could revolutionize backyard astronomy. All photos by Art Schmidt.

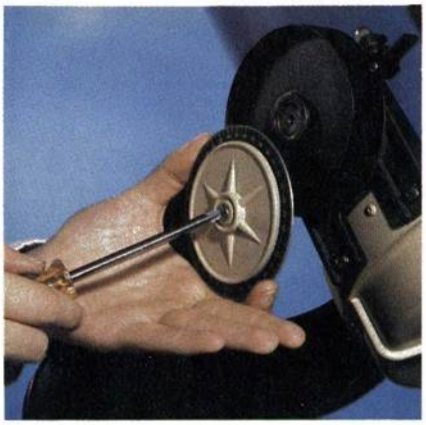
The ATI CAT System


Dec. Encoder
R.A. Encoder
Computer Console
Power Cord
Cables

Telescope is fitted with special encoders that measure the telescope's movement across the sky and inform the computer of changes.

Power cord supplies electricity to run computer.

Computer acts as "brain," storing information and calculating where to aim telescope.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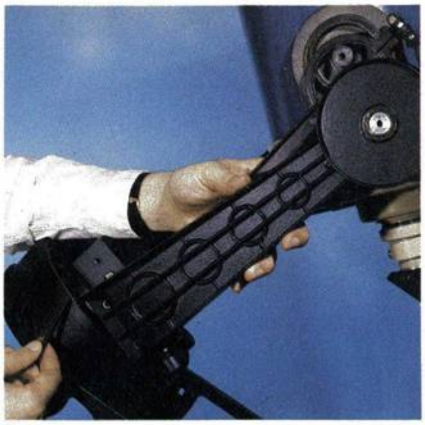
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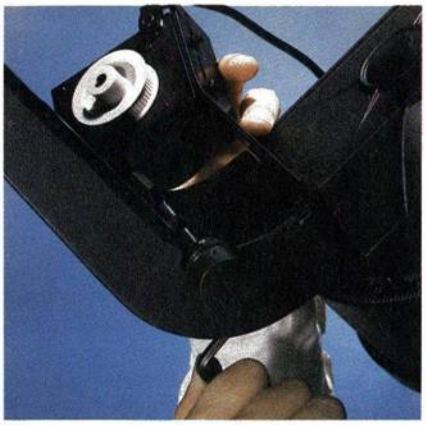
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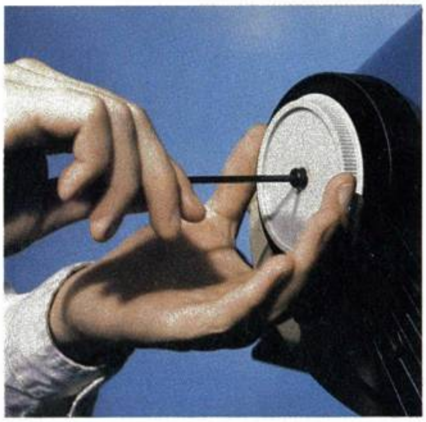
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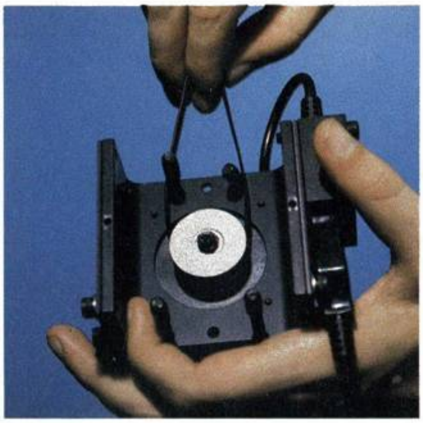
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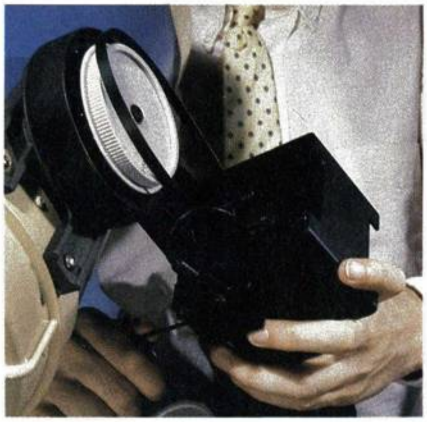
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The major steps in installing the CAT on an 8-inch Schmidt-Cassegrain telescope are shown in these two sequences. To install the right ascension encoder mechanics: (1) Remove the left-hand declination setting circle. (2) Remove the bolts holding the left-hand fork arm, take off the fork arm, and then slide a bronze bushing onto the declination axis. (3) Replace the fork arm but do not tighten the bolts. Slide the R.A. encoder plate between the fork arm and the R.A. base and tighten the bolts. (4) After popping off the cap from the R.A. base, place the R.A. pulley over the central hole and tighten it snugly. (5) Loop the R.A. timing belt around the small pulley on the R.A. encoder and the large pulley on the R.A. base. (6) Slide the R.A. encoder bracket to remove slack from the timing belt and tighten the bolts.

To install the declination encoder mechanics: (7) Remove the right-hand setting circle and bolt the large dec. pulley onto the dec. axis. (8) Loop the dec. timing belt around the small pulley inside the dec. encoder bracket, making sure it exits the bracket around the two closely spaced bolts. (9) Place the dec. encoder bracket outside the right-hand fork arm about 2″ below the pulley and bolt it onto the fork arm. (10) Loop the dec. timing belt around the large pulley and move the dec. encoder bracket to achieve the proper tension. (11) Bolt the R.A. connector block onto the dec. encoder mechanism. (12) Connect the R.A. and dec. encoder cables. The unit is now ready for testing.

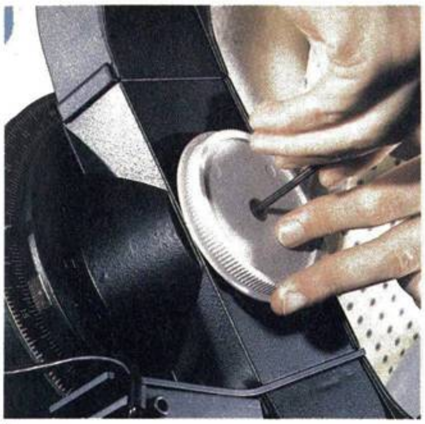
> **I installed the CAT on my vintage 1976 Celestron-8. The procedure only takes about half an hour and is not especially difficult because the directions are clear.**

ing from the search object. You move the telescope until the error bar lights go out and a central square lights up and — *voila* — the search object is in the telescope's field.

The *CNGC*, the unit's primary database, is the key to operating the CAT. It contains positional, brightness, size, and descriptive data on 7,840 deep-sky objects. Once the unit is up and running, you can punch in a *CNGC* number on the system keypad and within a few seconds move the telescope to the correct position by watching the red cross lights. Also stored in the unit is information on 351 stars. Of these, 250 bright stars are included to help calibrate the device by providing it with objects of known position. For example, you aim the telescope at Polaris, input its star number listed in the CAT manual, and the computer knows it is pointing at 2h07.2m, +89°14′. The remaining 101 stars are prominent double and multiple stars.

The CAT's two encoders function as monitors that record the position of the telescope and inform the computer console of any changes. Each encoder has a small timing pulley on a mounting bracket, a large pulley, and a timing belt. The encoders bolt onto a Schmidt-Cassegrain's two axes and, after the computer system has been calibrated, provide the computer with a reference frame. Once the telescope is aimed at a known star and the star's coordinates have been input, the computer stores this position in memory and can move to objects in its database relative to the set position.

How do the encoders accomplish this? First, when the telescope is pointing at a star of known position like Polaris, you input the position of the star into the computer. The computer then "knows where it is." The computer also knows where it is after you move the telescope and can predict where objects are if it knows their positions, because the encoders are attached to the right ascension axis and declination axis by pulleys and timing belts. When the telescope swings around in right ascension, for example, the pulley stays still, but the timing belt moves and so does a pulley connected to the right ascension encoder. The encoder feeds electronic signals to the computer that tell the computer how far the belt has moved, thereby providing the computer with an offset position from the calibration star.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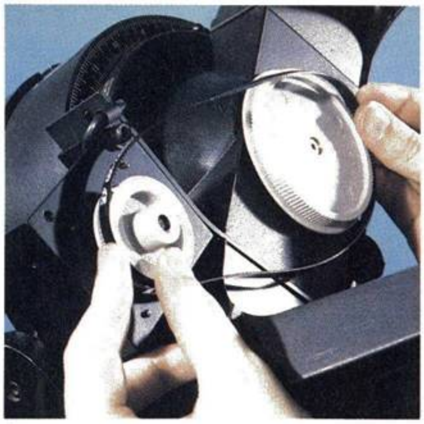
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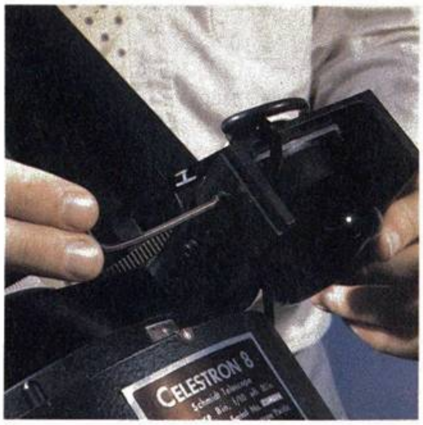

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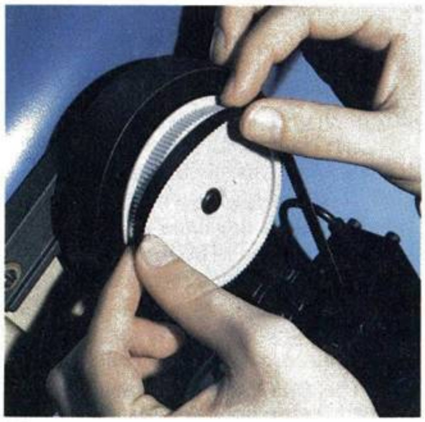
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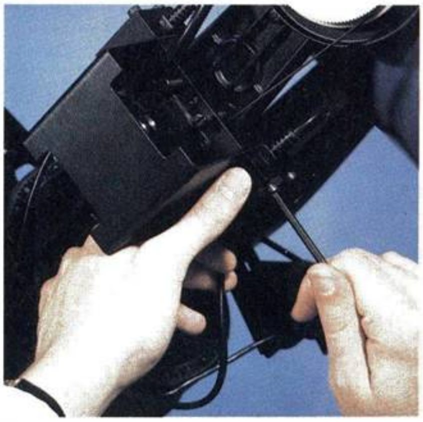
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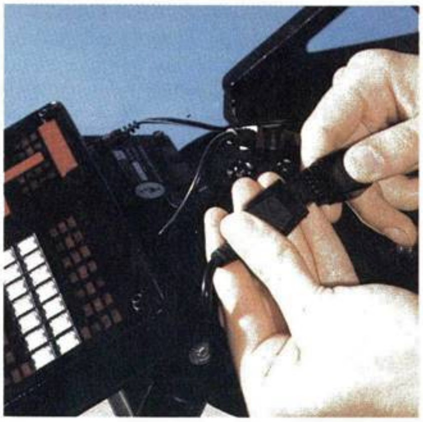

12

Accessories like a power cord and cables enable the telescope, computer, and encoders to work together. A long twin-wire cable, made foolproof with plugs that only allow it to be connected the right way, joins the encoders with the computer. The power cable allows you to use either a 9-volt battery or 12-volt car battery, which gives you flexibility if you're not near an AC outlet at your observing site. The power supply module lets you run the CAT from an AC outlet if one is available.

Installing the CAT

What does this device offer? Does it perform correctly and efficiently? Is it worth $1,995? Only after several days of reading the manuals, installing the device, playing around with it, and finally calibrating and testing it under a clear sky did I find the answers.

The CAT comes ready to mount onto a Celestron-8 telescope. With minor modifications, however, it can fit onto a Celestron-11, Meade 2080, or Meade 2010 telescope. (You can obtain the necessary information and modified parts from Advanced Technology Instruments to install the CAT on almost any telescope.) The manual supplied with the CAT has a section labeled "Custom Installation," which provides nine hints for adapting the CAT to virtually any telescope with the help of "a friend or local machine shop." To custom install a CAT, you'll need the assistance of someone who knows how to alter or build parts to fit your specific system.

I installed the CAT on my vintage 1976 Celestron-8. The procedure only takes about half an hour and is not especially difficult because the directions are clear and thorough. For installation — and later for calibration and use of the CAT — you'll need a complete set of Allen wrenches, an adjustable wrench, a flat-bladed screwdriver, a Phillips screwdriver, a straight edge, and anything else that fits your telescope's nuts and bolts.

Before you install the CAT, read the directions thoroughly so you're familiar with all the parts and know exactly what

The *CNGC:* A Built-In Catalog of Deep-Sky Objects

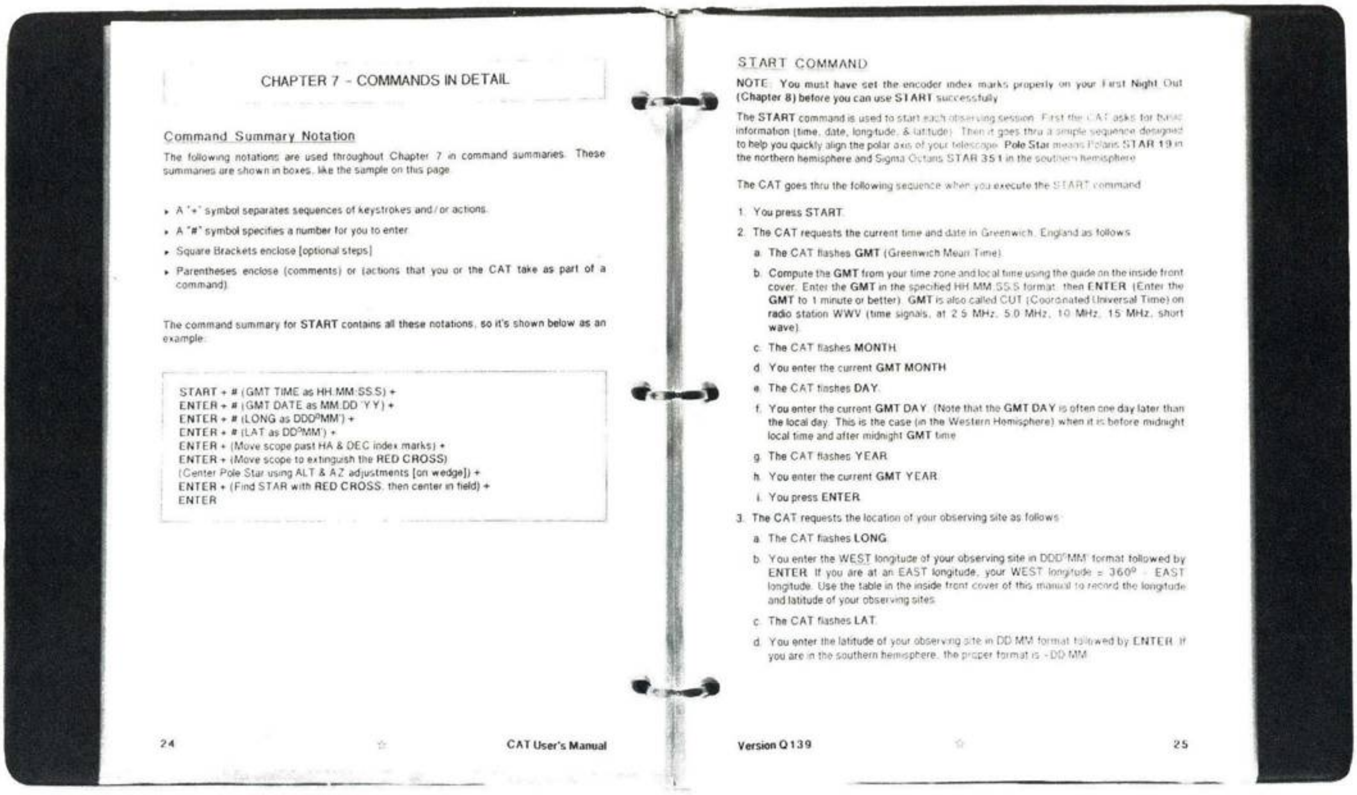
The greatest asset the ATI CAT offers is a wide variety of potential targets in the sky — 8,191 in all.

Of these 8,191 objects, the subdatabase of 351 stars contains 250 bright stars and 101 selected double and multiple stars judged especially attractive by the product's designer, Mike Simmons. Included for each star are an identification number, epoch 1988.0 coordinates, a description of the object, alternate names, a column giving coded evaluations of the object, and brief comments. I found the bright stars useful for making sure the unit was calibrated correctly after setup. Long before my eyes dark adapted, I was able to see Altair in the sky, punch in its star number (226), and move the telescope until the console lights indicated I was correctly placed on the star. Indeed I was. This gave me confidence to continue with other objects.

The most useful part of the database supplied with the CAT is the *Computerized New General Catalogue*, or *CNGC*. This giant listing is an updated version of the *New General Catalogue*, the standard list of deep-sky objects that began with William and John Herschel in the early nineteenth century. In 1973 an update of the Herschels' work called the *Revised New General Catalogue* (*RNGC*) was published, but it contains scant information on brightnesses and no sizes in its listings. Moreover, the *RNGC*'s coordinates are for epoch 1975.0.

Simmons improved on the *RNGC* by including epoch 1988.0 coordinates, sizes and magnitudes for most objects, a brief description of each object, alternate names, an evaluation of the object's visibility, and comments. Simmons' *CNGC* is therefore far more complete and up to date than its predecessors and consequently a valuable modern source of information for deep-sky observers.

— *David J. Eicher*



CHAPTER 7 - COMMANDS IN DETAIL

Command Summary Notation

The following notations are used throughout Chapter 7 in command summaries. These summaries are shown in boxes, like the sample on this page.

- A "+" symbol separates sequences of keystrokes and/or actions.
- A "#" symbol specifies a number for you to enter.
- Square Brackets enclose [optional steps]
- Parentheses enclose (comments) or (actions that you or the CAT take as part of a command).

The command summary for **START** contains all these notations, so it's shown below as an example:

```
START + # (GMT TIME as HH.MM:SS.S) +
ENTER + # (GMT DATE as MM.DD 'YY) +
ENTER + # (LONG as DDD°MM') +
ENTER + # (LAT as DD°MM') +
ENTER + (Move scope past HA & DEC index marks) +
ENTER + (Move scope to extinguish the RED CROSS)
(Center Pole Star using ALT & AZ adjustments [on wedge]) +
ENTER + (Find STAR with RED CROSS, then center in field) +
ENTER
```

24 ☆ CAT User's Manual

START COMMAND

NOTE: **You must have set the encoder index marks properly on your First Night Out (Chapter 8) before you can use START successfully.**

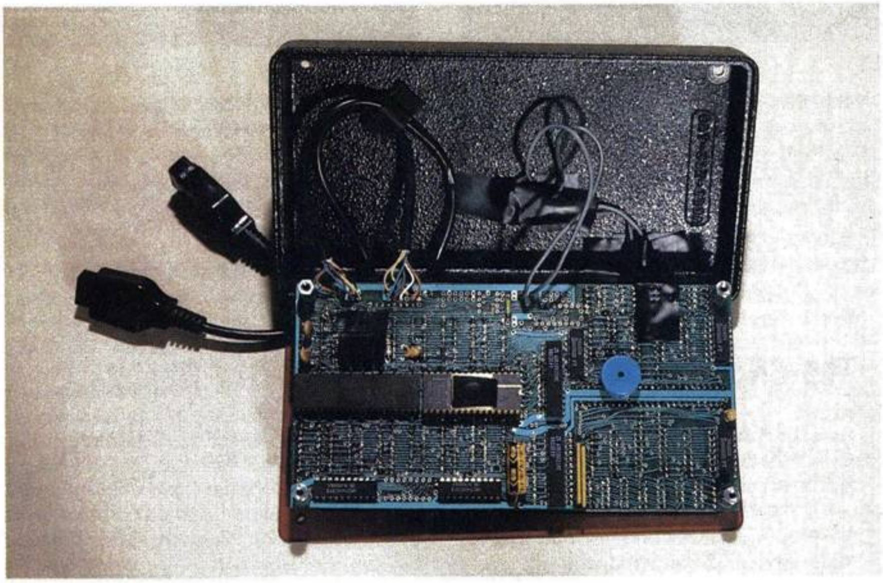
The **START** command is used to start each observing session. First the CAT asks for basic information (time, date, longitude, & latitude). Then it goes thru a simple sequence designed to help you quickly align the polar axis of your telescope. **Pole Star** means Polaris **STAR 19** in the northern hemisphere and Sigma Octans **STAR 351** in the southern hemisphere.

The CAT goes thru the following sequence when you execute the START command:

1. You press **START**.
2. The CAT requests the current time and date in Greenwich, England as follows:
   a. The CAT flashes **GMT** (Greenwich Mean Time).
   b. Compute the **GMT** from your time zone and local time using the guide on the inside front cover. Enter the **GMT** in the specified HH MM SS.S format, then **ENTER**. (Enter the **GMT** to 1 minute or better). **GMT** is also called CUT (Coordinated Universal Time) on radio station WWV (time signals, at 2.5 MHz, 5.0 MHz, 10 MHz, 15 MHz, short wave).
   c. The CAT flashes **MONTH**.
   d. You enter the current **GMT MONTH**.
   e. The CAT flashes **DAY**.
   f. You enter the current **GMT DAY**. (Note that the **GMT DAY** is often one day later than the local day. This is the case (in the Western Hemisphere) when it is before midnight local time and after midnight **GMT** time.
   g. The CAT flashes **YEAR**.
   h. You enter the current **GMT YEAR**.
   i. You press **ENTER**.
3. The CAT requests the location of your observing site as follows:
   a. The CAT flashes **LONG**.
   b. You enter the WEST longitude of your observing site in DDD°MM' format followed by **ENTER**. If you are at an EAST longitude, your WEST longitude = 360° - EAST longitude. Use the table in the inside front cover of this manual to record the longitude and latitude of your observing sites.
   c. The CAT flashes **LAT**.
   d. You enter the latitude of your observing site in DD MM format followed by **ENTER**. If you are in the southern hemisphere, the proper format is -DD MM.

Version Q 139 ☆ 25

Top: The CAT User's Manual contains detailed instructions for installing, calibrating, and using the device. It is a how-to explanation of the methods required to get the CAT up and running and a reference manual for commands, displays, and data for objects stored in the computer. The pages in this manual are plastic coated, so they can withstand moisture outdoors.



Left: Stored in these integrated circuits inside the CAT console is the *CNGC*, designer Mike Simmons' database of over eight thousand deep-sky objects. Just right of center is the tiny speaker that beeps to signify correct or improper alignment and calibration.

is supposed to be done. Don't be tempted to experiment as you go along, or you may install a part incorrectly or even ruin something in the process. Also, get a friend to help you install the CAT. During one part of the installation you'll need to demount the telescope tube from the fork arms, and without a friend you trust enough not to drop your telescope, you may succeed only in seeing the tube fall to the ground.

The first step in installing the CAT is to bolt the right ascension encoder to the base of the left-hand fork arm. This takes a few minutes and is easy to do with the instructions in the manual. The second step is fitting the declination encoder onto the right-hand fork arm. I mounted this assembly in a few minutes using three sizes of Allen wrenches, which made the total installation time half an hour. After installing the right ascension and declination encoders onto the telescope, you're ready to test the CAT.

Testing the CAT

Testing the CAT involves making sure the electronics and mechanical components are going to work properly when you get out under the stars. Plug the unit's power supply into a wall outlet and attach the jack to the back of the console. The LEDs should flash for a few seconds and the console should emit a tone, which tells you that electricity is moving through the system. Now that you know the console is operating properly, unplug the power supply and attach the encoder cables. Plug in the power supply again and see if the LEDs flash and the speaker emits a tone. If they do, all is well and you are ready to adjust the pressure on the encoders, which needs to be set just right.

Rotate the tube in declination through several revolutions; if you hear a tone, there's too much pressure on the declination encoder shaft and you'll need to reposition the shaft. Now rotate the telescope in right ascension back and forth several times. If you hear a tone, there is too much tension on the right ascension encoder shaft and you need to reposition that shaft. If you don't hear tones throughout this process, you're ready for your first night out.

Your First Night Out

Calibrating and using the ATI CAT on my portable, old-style Celestron-8 was a complex and fairly difficult process the first couple of times out. Begin the procedure by precisely polar aligning the telescope, making sure the tripod is level, calibrating the encoders on Polaris so they know where they are, running through a START command that initializes the machine, and moving to several stars to see if everything is operating correctly. Even if you've read through the manuals and have all the necessary tools on hand — two crucial steps — the first couple of times through this procedure are painfully slow. Setting up and critically aligning the encoders was frustrating, because my telescope does not have a mechanism for moving the base along the azimuth axis; I had to nudge, kick, or bump the tripod to the correct spot. However, aligning more recent models should be easier.

You must next calibrate the right ascension and declination encoders. Your telescope will be pointing at Polaris (because you just aligned the encoders to it), so you can use Polaris as a calibration star. The first step is to execute the START command on the console by pressing START. You must then enter the current Greenwich mean time (GMT), which can be calculated easily with a table in the front of the manual. Then enter the current month, day, and year, your observing site's west longitude in degrees and minutes, and your site's latitude in degrees and minutes. You're now ready to calibrate the encoders.

Carefully loosen the bolt that holds the pulley onto the right ascension axis and rotate the pulley until you hear a "beep." The beep tells you you have reached the appropriate zero point on the pulley corresponding to the position of the north celestial pole. Tighten the bolt and make sure the beep continues after the bolt is tightened. The device is so sensitive that this is slightly tricky; you may need to experiment with this for some time before getting the correct touch to sustain the beep. After tightening the bolt, move the telescope slightly in right ascension so the beep stops. Now do the same for the declination pulley. Press ABORT and then use the START command again. After going through the START command, you're ready to observe.

The CAT has several commands and modes of operation. START begins an observing session. SYNC allows you to recalibrate the computer's accuracy by aiming the telescope at a known star, inputting the star number, and pressing SYNC. It is an extremely handy tool for increasing the precision of the CAT's operation.

The CNGC, STAR, and M commands tell the computer to display data for any of the stars or deep-sky objects in the database. DISP displays information like the latitude and longitude of your observing site. SET allows you to set longitude and latitude, Greenwich mean time (GMT), or start a built-in timing clock for astrophotography. REV reverses the direction of the timer, the previous SYNC, or the direction of searches in the FIND command. TIMER starts and stops a timer. FIELD identifies the *CNGC* object nearest the center of your telescope's field. This could be extremely useful for observing areas cluttered with many objects or for comet hunting. FIND tells the CAT to look through its database for objects that fit criteria you input. NEXT goes to the next object in a FIND sequence. ABORT stops any command that has been executed. OPT, short for option, is used for special applications like future accessories.

The CAT costs a considerable sum, but the payoff is one unthinkable a few years ago: an automated, self-guided tour of the universe.

A Computer-Aided Observing Run

Once it was ready to go, the CAT was fun and easy to use. Although I tested it at a relatively light-polluted suburban site, I was able to find bright stars with relative ease. First I moved the telescope away from Polaris and aimed it at Vega, a blazing blue-white mass of light in the 40′ field of view. As a first test I decided to place the scope at Vega and see if the red cross lights were dead on after I entered the star's number.

I went back to the manual and found the star number for Vega, 214. (A somewhat annoying effect of the database is having to learn arbitrary star numbers for the 351 stars.) I pushed STAR on the keypad, entered 214, and pushed ENTER. The red cross showed two rectangular lights on each axis, having missed Vega by just a few arcminutes. This slight error didn't keep Vega from lying inside the field of view, however. There it was in the eyepiece, shining as brilliantly as ever.

Just as I started to feel confident, though, disaster struck. I walked over to the manual, found that Altair's star number is 226, and entered the number with the STAR command. Because the telescope still pointed at Vega, the red cross lights indicated the aiming was way off. I unlocked the clamps on the scope's right ascension and declination axes and slowly, over the course of fifteen or twenty seconds, moved the scope toward Altair. When I got into the immediate vicinity of the star, the lights were still way off. Something had gone wrong.

After checking the manual and pondering my suspicions, I concluded the culprit was probably poor tripod leveling and lack of high-precision polar alignment. The old Celestrons offer no way of rotating the wedge along the polar axis, so the polar alignment — although quite close — could have been better. It was difficult to level the telescope because the tripod rested on a bed of slightly damp grass.

Luckily there is a way to alleviate this problem. By aiming the telescope at Altair and using the SYNC command, which allowed me to recalibrate the computer's accuracy by telling the computer it was aiming at Altair while I had the bright star centered in the eyepiece, the situation improved. Now I entered the star number for Gamma Cassiopeiae, saw the red cross light up in an instant, and leisurely moved the telescope toward the northeastern sky. Sure enough, after the five seconds required to move the scope so the center light in the cross lit up, Gamma Cassiopeiae lay dead center in the field of view.

The SYNC command made the CAT work despite the imperfect polar alignment and leveling of the telescope. The polar alignment procedure is tricky and time consuming, so I expect that many users may not hit the north celestial pole right on the head. It was reassuring to discover that occasionally using SYNC saved the usefulness of the device that night.

Is the ATI CAT worth all the effort and money? I think that owners of permanently installed telescopes will certainly find the CAT invaluable for finding deep-sky objects. And although the hassles of setting up and calibrating the device on a portable instrument are considerable, the reward after the device is operating is great.

The CAT will certainly be useful for small professional observatories and astronomy clubs with permanently mounted instruments. It will likely become the hot new novelty item for those with lots of money to spend on the hobby. But what about the typical amateur astronomer on a limited budget?

The real benefit is that the device helps you quickly and efficiently find many deep-sky objects you might not otherwise be able to find as quickly or perhaps at all. I expect that experienced deep-sky observers with a thorough knowledge of the locations of deep-sky objects may not find such a device useful. After all, many observers have memorized dozens of stars patterns and can star hop to NGC-4565 in seconds. But for those without years of deep-sky experience, the CAT is a true time-saver, a device that can show hundreds of objects per night.

For the majority of sky watchers the CAT is probably a sound investment. The device costs a considerable sum, but the payoff is one unthinkable a few years ago: an automated, self-guided tour of the universe.

— *David J. Eicher*

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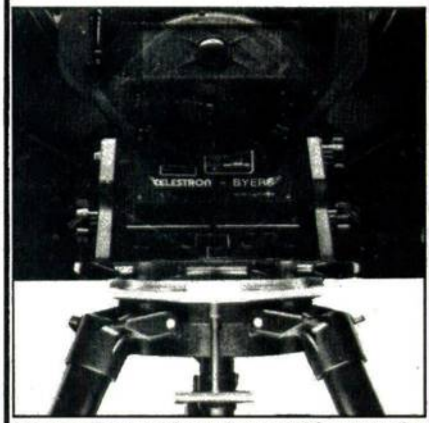

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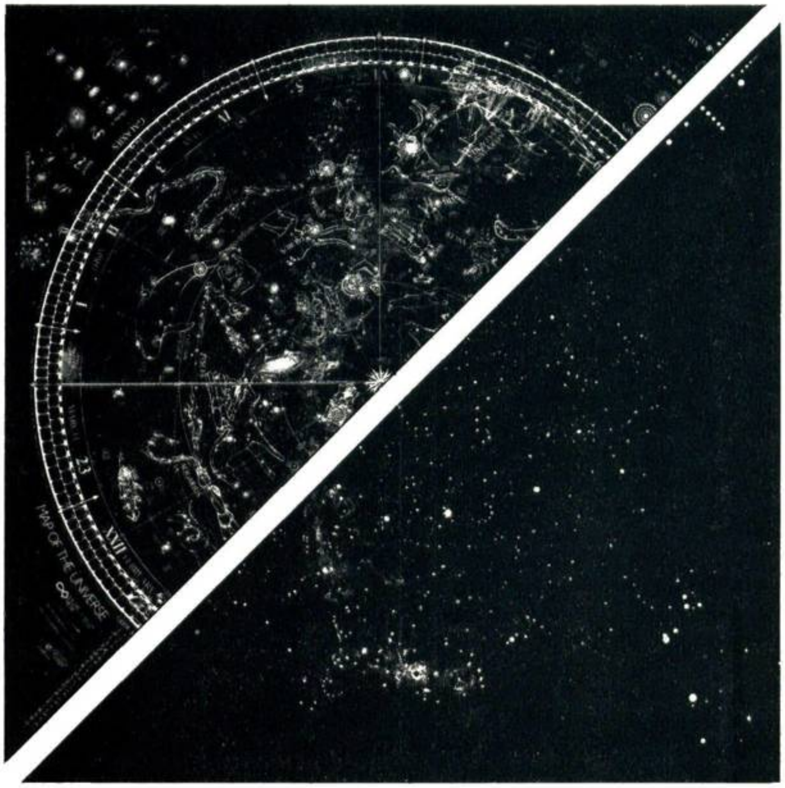

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Gazer's Gazette

How to Discover a Comet

by David H. Levy

Several times a year someone discovers a comet that has never been observed before. Professional astronomers discover many comets on photographic plates. But each year some comets escape the scrutiny of the photographic emulsion and are spotted first by vigilant amateur observers equipped with good telescopes, dark skies, and plenty of patience.

Comet hunting is not an activity for people who want quick success. If you decide to search for comets, you should know the odds are stacked heavily against you. Because there are relatively few comets out there to be discovered and many watchful comet hunters located around the world, the search can require years of painstaking work at the telescope. However, despite the competition and the long hours, searching for a new comet can be a lot of fun. And, needless to say, so is discovering a comet of your own.

Several factors can increase your chances of making a comet discovery. For example, comets are brightest when near the Sun, so they first become visible either in the evening sky or in the morning sky within about 90° of the Sun.

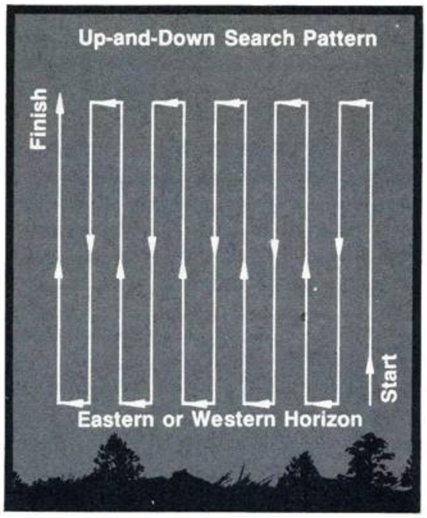
No two comet hunters use the same technique, but they share a common goal: to cover the regions of sky in which comets are likely to be found. These regions lie within 45° of the western horizon two or three hours after sunset and within the same altitude above the eastern horizon two or three hours before sunrise.

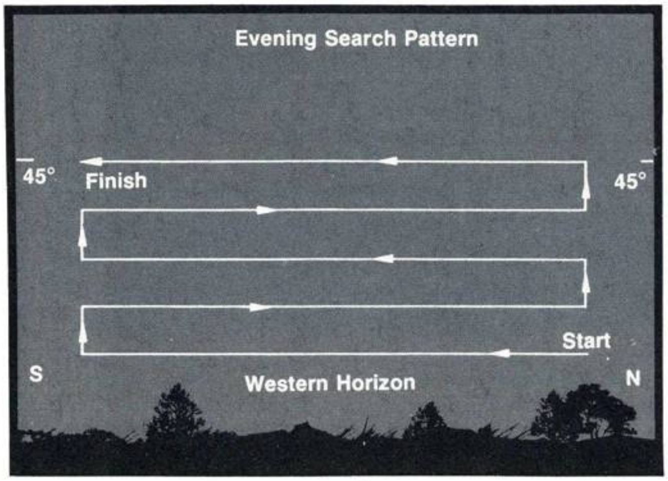
The specific search procedure is not as important as being certain you have covered your search area thoroughly. Always use an efficient pattern of sweeping: I recommend hunting up and down in parallel strips of sky, overlapping coverage slightly. A good night's searching might cover the sky within a couple of constellations before the search area sinks too far toward the horizon or twilight invades in the morning.

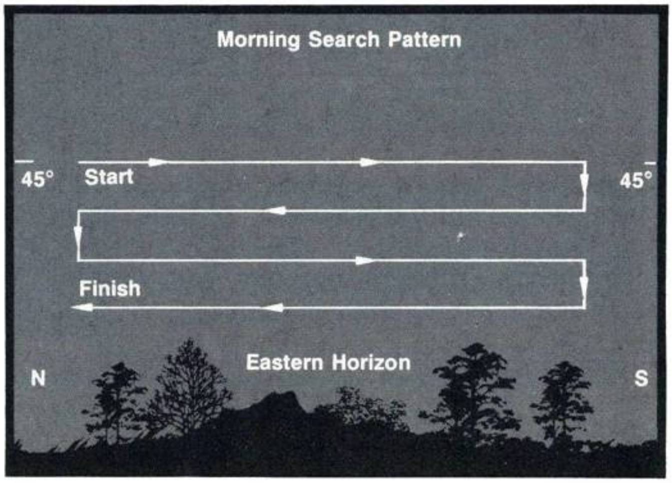
Another method is to make slow, methodical horizontal sweeps in these comet-prone regions. If you search in the evening, begin forty-five minutes after sunset about 45° north of where the Sun has set and as close to the horizon as possible. Sweep parallel to the horizon until you reach a point 45° south of the sunset point. Raise your field of view slightly and then reverse the sweep so you scan south to north. Continue this zigzag sweeping, elevating your field after each pass, until you reach an altitude of 45°.

The morning search procedure is similar to evening's except that you begin sweeping 45° above the horizon — 45°

To look for comets you can either sweep perpendicular or parallel to the horizon in overlapping strips of sky 45° above the horizon. The up-and-down method (below) covers select regions of sky. The horizontal method (bottom of page) systematically covers the sky within 45° north and south of the sunrise or sunset point.







Top: Comet *IRAS*/Iraki/Alcock stirred up worldwide interest in comets when it passed only 4.6 million kilometers from Earth in May 1983. The comet was first detected by the *IRAS* satellite and independently by G. Iraki and E. Alcock. Photo by Henry Nebel.

Above: Comet Levy-Rudenko (1984t) is visible near the bottom right edge of this photo; the spiral galaxy M-81 is at the top edge. The comet image is slightly elongated, showing the motion of the comet during the 15-minute exposure. Photo by Geoff Chester.

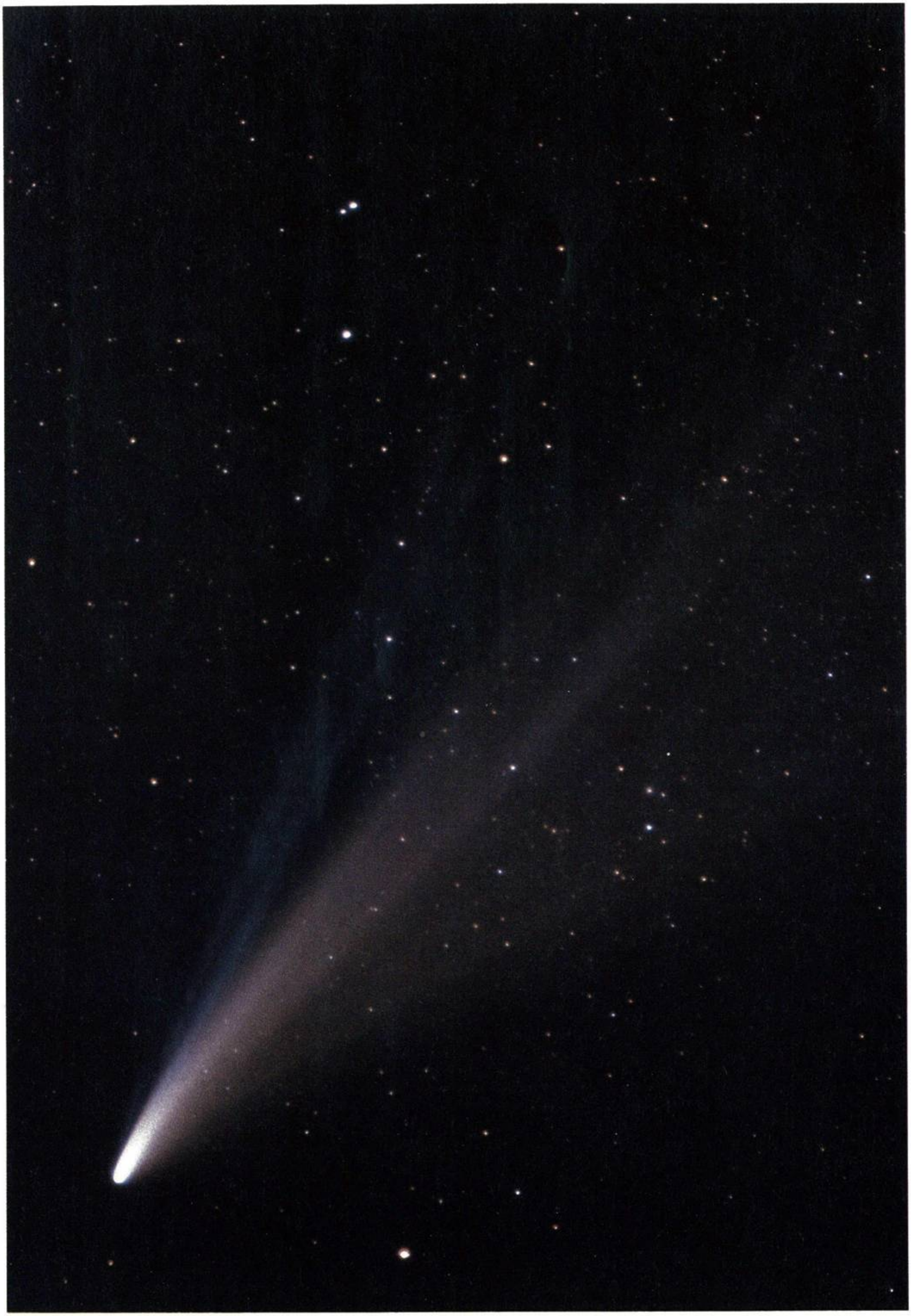
Along the left side of this page are a few Messier objects you might "discover" while comet hunting. At the top is M-53, a globular cluster in Coma Berenices; M-1, the Crab Nebula in Taurus; and M-49, an elliptical galaxy in Virgo. At the bottom is a real comet, Kobayahsi-Berger-Milon (1975h), which appears as a blue fuzzy object near the center of the field. Photos are by Lee Coombs, John Kerns, Jack Newton, and Steve Reed, respectively.

north of the sunrise point — and work your way down. The entire procedure should take you two to three hours, unless you stop frequently to check out a suspected object. This means that to adequately cover the morning sky, you must begin your search well before dawn.

You may think any time the Moon is not in the sky is a good time for comet hunting, but actually there are certain times when the Moon is in the sky that may be better than moonless nights. The best chance for success in the evening sky is just after a Full Moon and in the morning sky around New Moon. The reason for this curious condition is that moonlight acts as a curtain. During the two weeks the Moon dominates a certain part of the sky, a faint comet hiding in that region has a chance to brighten and develop structure. Then, when the Moon leaves, the curtain opens to what could be a rather bright yet undiscovered comet. You have to be out looking in this region before someone else finds a comet first.

Bear in mind, though, it is still possible to find a comet well away from these prescribed areas. For example, Comet *IRAS*-Araki-Alcock, 1983d, was discovered in a rich Milky Way field high in the sky and nowhere near the horizon because it had brightened very rapidly as it approached Earth. But statistically most comet discoveries are made in the early morning and evening sky.

The type of telescope and eyepiece you use can also give you an edge in finding comets. Use a low-power eyepiece with



a wide field of view, preferably three quarters of a degree or more. This will minimize the amount of time you take to search large areas of sky (you would search endlessly with the limited field of a high-power eyepiece). If you come across a faint, fuzzy object, switch to a higher power eyepiece to investigate your find: you may have stumbled across two close double stars or a small, unresolved cluster. Higher magnification provides the advantage of greater contrast. This enables you to discern faint diffuse objects from the sky background.

Vital to finding a comet is a telescope with an aperture large enough to detect faint, nebulous patches of light. A reflector of 3 to 4 inches is too small for serious comet searching. Most newly discovered comets are a feeble 9th magnitude or fainter. Then, too, other comet hunters are certain to be using at least 6- or 8-inch reflectors, which will reveal even 10th-magnitude objects with ease.

Some comet hunters use even larger instruments capable of showing fainter comets yet, though larger apertures suffer from smaller fields of view. On the other hand, larger telescopes between 10 and 20 inches allow the comet hunter to see more detail in suspect objects and to more easily differentiate comets from deep-sky objects.

Just as important as a good telescope is a well-trained eye that has seen enough galaxies, clusters, nebulae, and comets to tell the difference. Observing all the Messier objects is fine preparation for a prospective comet hunter. Perhaps the best way, though, is to locate and follow recently discovered comets or periodic comets.

What do you do if you think you have found a comet? First, look for an obvious tail appearing either as a spike of light emanating from the object or a faint fan of light curving away from one side. Although chances are against seeing a tail, if you are fortunate enough to detect a tail, your comet-identification problem will be lessened, to say the least. Otherwise you will have to identify the object by its position and motion.

Comets that have developed short tails lack the bilateral symmetry of spiral galaxies and the partial resolution of a distant star cluster. Typically a new comet appears as a faint, weak patch of misty light without obvious structure. Its surface brightness may be only slightly greater than that of the surrounding sky. A galaxy, on the other hand, normally shows as a patch of nebulous light with a rather sharply defined center and a symmetrical envelope of nebulosity. These distinctions hold true generally, but out under the stars distinguishing a galaxy from a suspected comet can be tricky.

Opposite page: Comet West, discovered in 1975 by Richard West of the European Southern Observatory. Photo by Bill Gordon.

Another important comet hunting tool is a good star atlas such as Tirion's *Sky Atlas 2000.0* or *Uranometria 2000.0*. Such an atlas shows the position of virtually every cluster, nebula, and galaxy you could possibly stumble across in your search for a comet. If you suspect that the fuzzy blob in your eyepiece is a comet, you need to make sure you haven't "discovered" a globular cluster or a faint elliptical galaxy. Look for distinctive star patterns around the fuzzy object and then find these patterns in a star atlas. Look to see if a deep-sky object is charted at the position of the nebulosity in the sky relative to the star patterns. If there's nothing there, you may well have found a comet or an object not plotted on your atlas.

To be absolutely certain, you need to determine whether or not the object is moving. Carefully sketch the object's position relative to the starfield and observe the object half an hour later. Compare the position against your sketch. In almost every case a comet will reveal itself by moving slightly in that short time period. A nebula or galaxy, of course, won't move.

Even if you have found a comet, you may not have discovered a new one. At any time there may be half a dozen previously cataloged comets in the sky bright enough for 6- to 8-inch telescopes. Here's where a professional astronomer can help, because he or she is aware of the known comets in the sky and of the ones currently making an apparition.

After confirming the sighting, report your discovery as soon as you can to the Central Bureau for Astronomical Telegrams, Smithsonian Astrophysical Observatory, Cambridge, Massachusetts. The Central Bureau is the official clearinghouse for astronomical discoveries. Include the following information organized as given below. This allows the Central Bureau to double-check your report, thus lessening the chance for error. It also helps to keep you thinking clearly despite your excitement. The information below is based on my second comet discovery, made on January 5, 1987.

1. *Name of discoverer.* (Levy)
2. *Type of object.* (Comet)
3. *Name of observer.* (Levy)
4. *Equinox and position accuracy.* Indicate whether you are using 1950 or 2000 coordinates and the accuracy of your position: 1 indicates an approximate position; 2 indicates an exact position. (19501)
5. *Date of observation.* Use the last digit of the year, then the month and the day. The value below is for 1987, January 5. (70105)
6. *Time of observation.* Convert UT to a decimal value by dividing UT by 24 hours. In the example below the observation was made at 12 UT. This converts to 0.50000. (50000)
7. *Right ascension of comet.* Example: 17 hours, 17.5 minutes. (17175)
8. *Declination of comet.* Example: +11° 20'. If comet position is south of celestial equator, 1 precedes series; if comet position is north, 0 is used. (01120)
9. *Numerical description of comet.* Use 01 if the magnitude estimate is for the whole comet; 02 if the magnitude is of the nucleus only; the next two digits represent the estimate itself; and the last digit describes the condensation of the comet's nucleus on a scale of 0 to 9 (0 for a uniform coma, 9 for a stellar nucleus). Hence, the magnitude estimate below is for the whole comet at magnitude 10 with a slight condensation in nucleus. (01102)
10. *Number check.* Add all previous values (which would total 159003) and include the last five digits of the sum. (59003)
11. *Double number check.* Add the values from sections 7, 8, and 9 only and use the last five digits from the sum. (19397)
12. *Full name, address, and telephone number of the observer/discoverer.*

Send the message by telex to the Central Bureau. The toll-free number for Western Union is 1-800-325-6000; you can phone in your message anytime, day or night. The telex number for the Central Bureau is TWX 710-320-6842 ASTROGRAM CAM, CENTRAL BUREAU FOR ASTRON CAMBRIDGE MASS. To send a telex, call Western Union and give your message and the telex number; this is usually the fastest method of reporting. Follow this report with a letter to the Central Bureau confirming your message.

If your discovery is subsequently confirmed, the comet will be designated with your surname. For example, the comet that is currently making a bright apparition in the sky, Comet Bradfield, was discovered by William Bradfield, an Australian amateur observer who has discovered thirteen comets. A new comet is also labeled with the year it was discovered and a letter indicating the order in which it was discovered relative to other comet discoveries made that year. Thus Bradfield's most recent comet is designated *1987s*, the nineteenth comet discovered in 1987.

The life of a comet hunter moves in chapters from one dark Moon to the next. Comet hunters are not forced into the work; they do it by choice. The search is demanding and fraught with frustration and disappointment, but a single discovery is its own reward. The enthusiasm of all comet hunters is what sustains them in their search.

David Levy is an observer with the International Halley Watch and the discoverer of two comets. He is the author of several books about astronomy including Observe: Meteors, *which he co-authored with Stephen Edberg, and a book on variable stars to be published by Cambridge University Press in 1988.*

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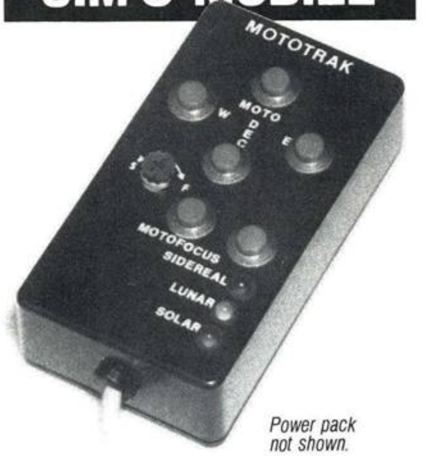

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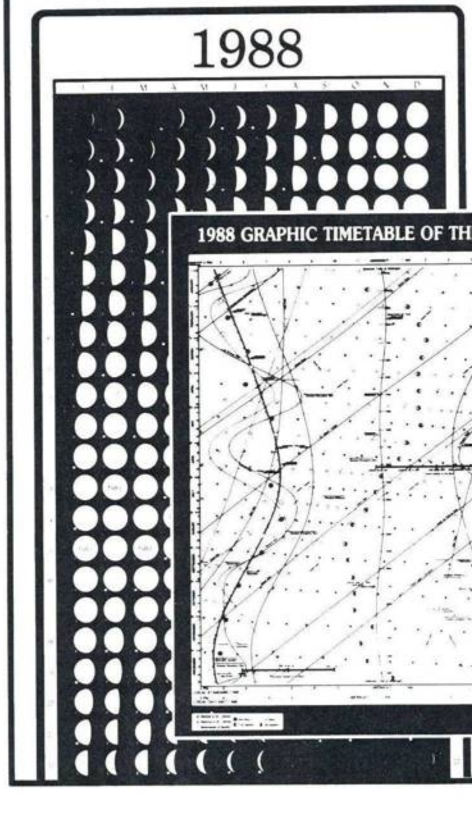

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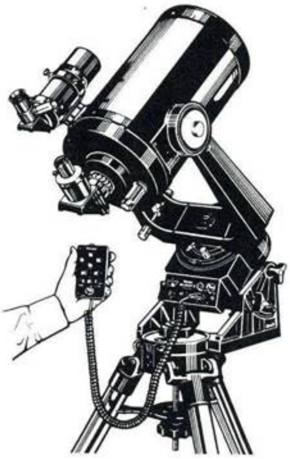

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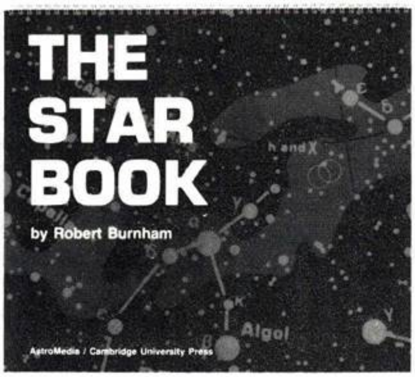
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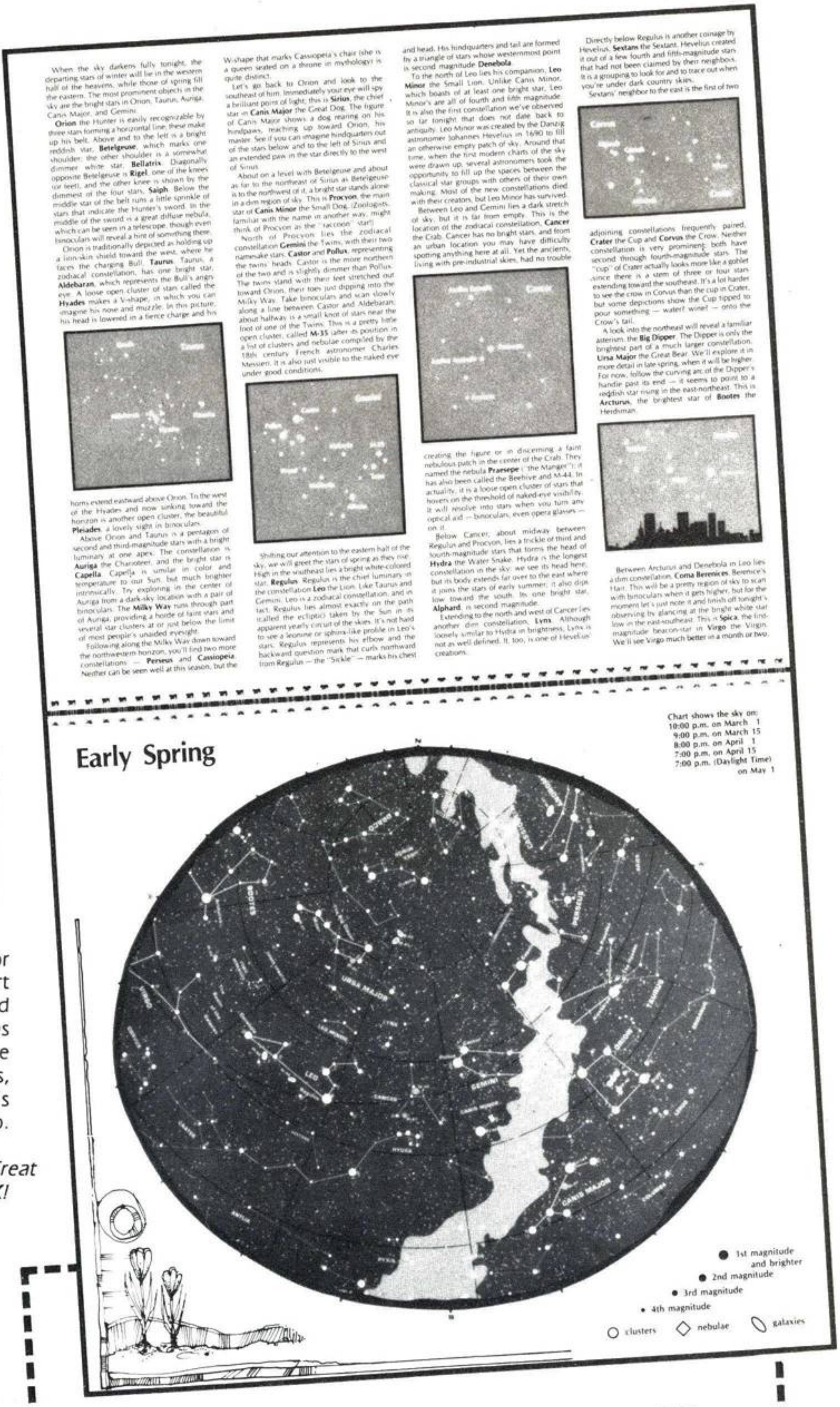
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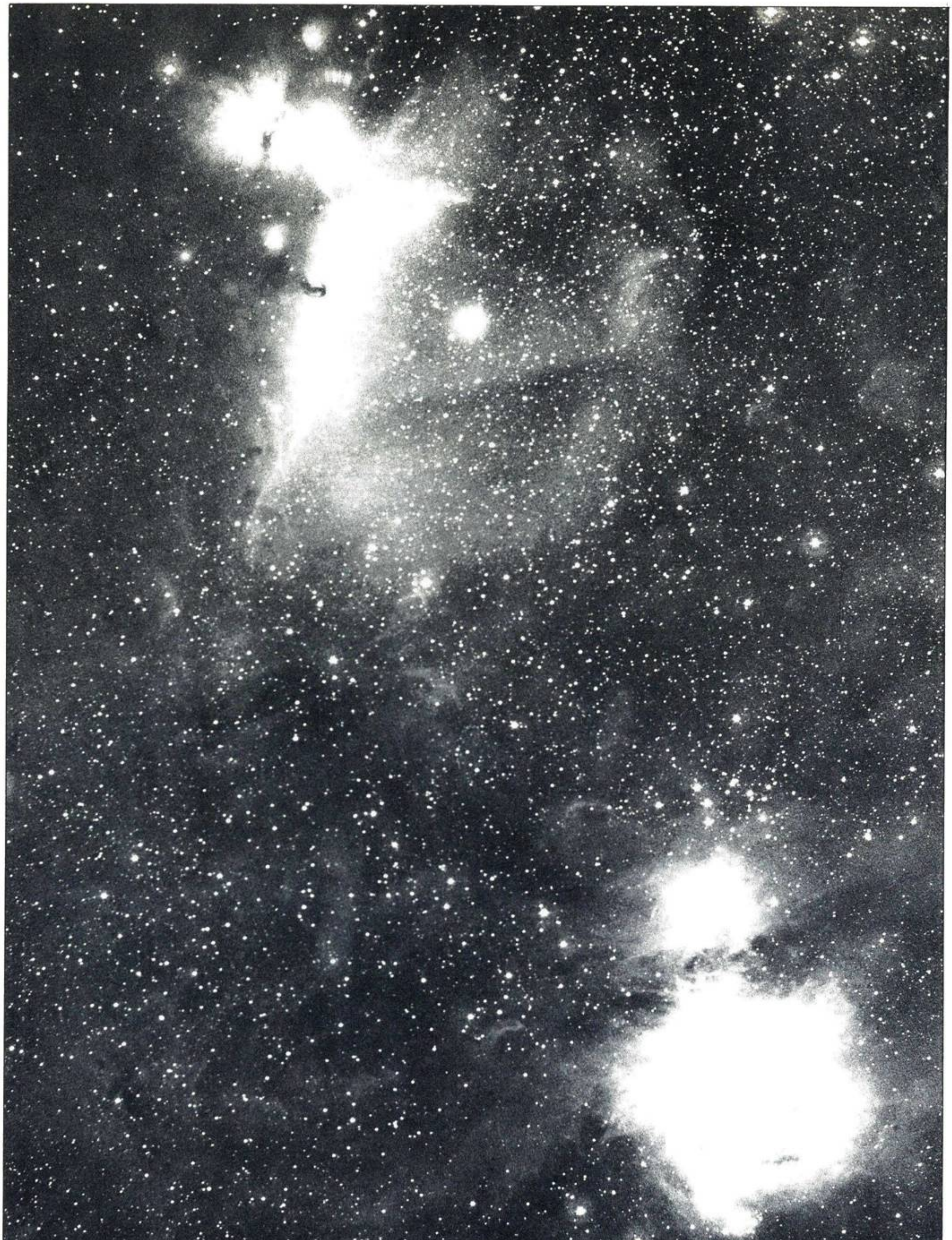


Crisp star images and faint nebulosity characterize Schmidt camera photography. In this deep exposure of Orion's belt and sword region the entire field is filled with glowing nebulosity; the Orion Nebula (lower right) is completely overexposed. Robert Reeves took this picture with an 8-inch f/1.5 Schmidt camera made by Celestron International.

Taming the Schmidt Camera

by Robert Reeves and Mace Hooley

Nobody can deny the Schmidt camera is one of the best things to happen to astrophotography. Since Schmidt cameras were introduced to the amateur market fifteen years ago, they have given amateur astrophotographers the capability to shoot professional-quality images of the heavens. Furthermore, the properties of Kodak's incredible high-contrast, fine-grain Technical Pan film are a near-perfect match to the Schmidt camera's combination of superb resolving power, wide field, and high speed.

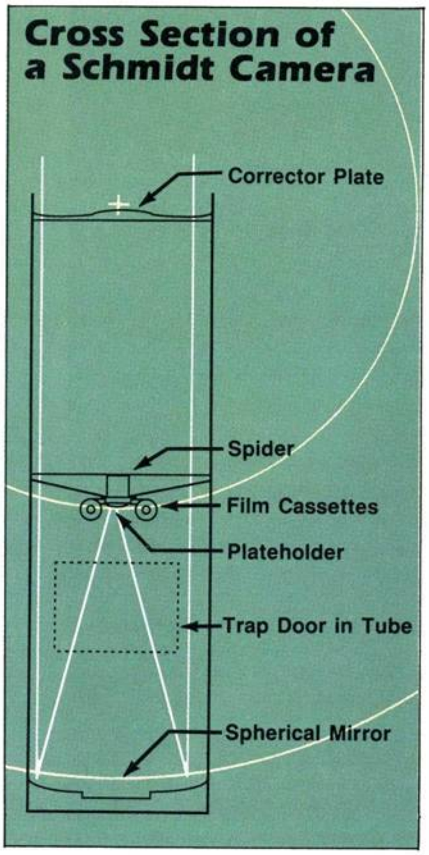
How Schmidt Cameras Work

While neither of us would trade our Schmidt cameras for anything, we will admit that until you learn the operating routine, a Schmidt camera can turn on you like a snake and bite you in a second. Taming these beasts takes skill, patience, and plenty of practice.

Schmidts work because they elegantly combine two optical principles in a single optical instrument. To provide pinpoint images, the Schmidt uses the catadioptric principle: it combines a strongly curved spherical mirror that focuses light with a weak correcting lens that makes the image formed by the mirror sharp. The strong curvature of the mirror allows the focal length of the camera to be very short compared to that of conventional telescopes. Focal ratios faster than f/1 are feasible, though most Schmidts have focal ratios between f/2 and f/3.

To cover a wide field, the Schmidt uses the geometric principle of symmetry. When the weak corrector lens is placed at the center of symmetry of the mirror, incoming starlight "sees" the same optical system over a wide range of angles. This means the camera forms sharp images over a wide field of view — up to 30° in some cases.

The Schmidt camera forms its sharp, well-corrected image on a spherical surface. That means for sharp images the film must be bent into a small section of a sphere. But film comes flat — so you must bend it to the required curve in a special "plateholder" that fits inside the camera.



Cross Section of a Schmidt Camera

Because the image forms inside the camera midway between the corrector lens and the spherical mirror, you must open the camera to put the film in the plateholder at the focus. And something has to hold the plateholder in place in the middle of the optical system. Furthermore, the plateholder and its support block some of the incoming starlight. While these are not severe problems, they do make using a Schmidt camera a walk on the wild side.

Film Is a Wild Animal

The need for bent film makes the Schmidt camera a beast; placing those tiny pieces of bent film in little plateholders inside the camera in total darkness makes the Schmidt camera a wild beast. Just when you think your Schmidt is tamed, you lose a whole night of photos to some minor glitch in your film-handling technique.

You'll have to pay special attention to handling and preparing the film, loading the film into the camera, and developing it afterward, as well as to the logistics of operating the shutter, guiding, and protecting the camera's optics from dew before you tame the camera.

A commercial Schmidt camera comes with a plateholder to support a single "chip" of 35mm film precisely at the focus of the mirror. To take a picture, the photographer must first load a film chip into the plateholder and then, without exposing the film to light, reach inside the camera through a door on the side of the camera and press the plateholder gently against a magnetic button on the spider. A locating pin on the spider aligns the plateholder and the magnetic button holds the plateholder securely in place.

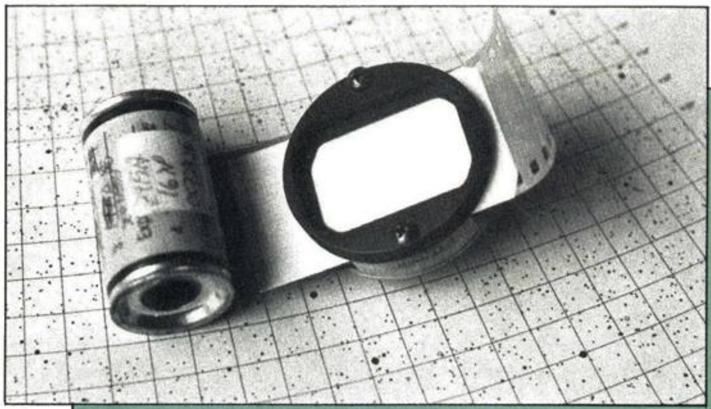
The photographer withdraws his hand, opens the shutter of the camera, makes the exposure, closes the shutter, and then reaches into the camera to remove the plateholder, removes the film, and places it into a box for development.

As darkroom buffs soon realize, developing several dozen tiny chips of film is not easy. Schmidt photography is definitely not the "you press the button and we do the rest" type of photography that made Kodak a household word.

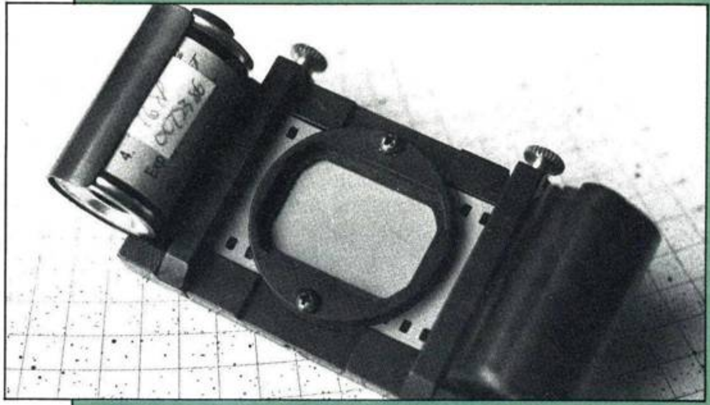
Loading a Plateholder

You must load film into the plateholder in total darkness. The most common way to do this is in a photographic changing bag, a large black cloth sack with sleeves attached. Slide a large cardboard box into the changing bag before you zip the bag shut so you can handle a plateholder, the raw film supply, an exposed film box, and a pair of scissors inside the bag. The box allows you lots of room to work, and the bag doesn't collapse on your hands.

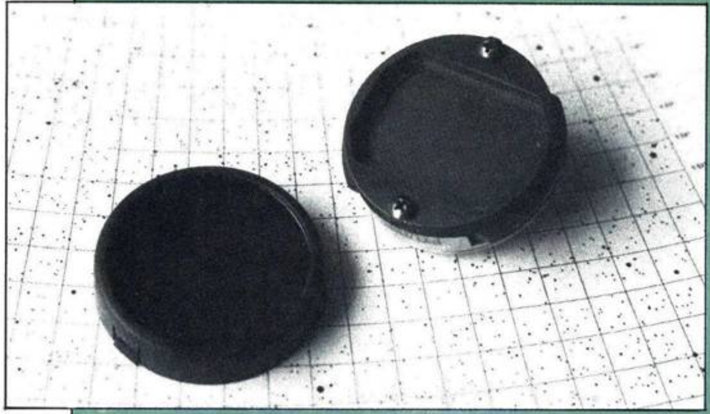
Loosen the set screw in the plateholder to release the pressure plate. This allows the 35mm film to slip between the plateholder frame and the pressure plate. At this point, fold a precut piece of paper



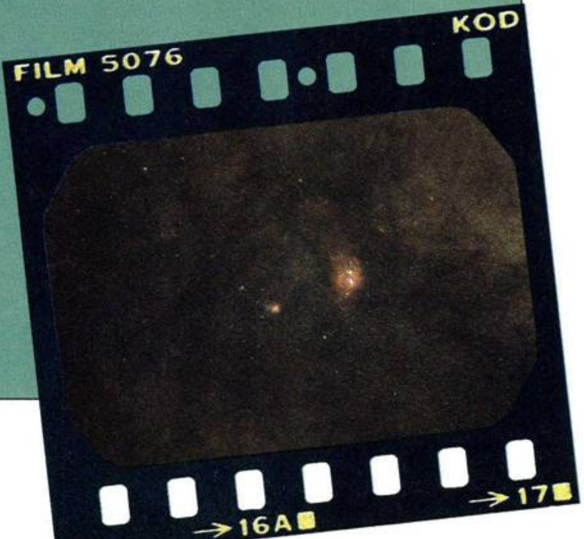
Use a slip of paper to protect single chips of film when you load them into a plateholder.



A roll holder greatly eases advancing the film to the next frame.



The filter carrier fits over the plateholder and enables you to make "deep" exposures.



This developed "chip" of 35mm color film can be mounted in a plastic slide holder. Photo by John Gleason.

around the film and slide the film into the holder with the paper in front of the emulsion. The paper protects the sensitive surface of the film from scratching as the film is drawn into the plateholder. When the film is in place, slip the paper out. Tighten the set screw to clamp the film firmly in place, cap the plateholder with its dark slide, and remove the loaded plateholder from the bag.

Loading Film with a Roll Holder

Schmidt-camera manufacturers went a long way toward taming Schmidt cameras by introducing film cassette holders. The idea behind the cassette holder is very simple: Instead of putting one piece of film at a time into the plateholder, you hang two 35mm film cassettes inside the camera. The film comes out from one cassette and into the other. To change from one frame to the next, the photographer need only remove the plateholder from the camera, loosen the set screw, roll the film from the feed cassette to the take-up cassette, tighten the set screw, and replace the assembly in the camera.

The roll holder need not be any more complicated than a couple of bent paper clips that keep the film cassettes from dangling loose inside the camera (see "An Inexpensive Roll Film Holder for Schmidt Cameras" by Robert Reeves, Photography in Astronomy, February 1984). Or you can purchase a roll film adaptor for Schmidt photography from the company that made your Schmidt camera. Either way, a roll holder allows much easier handling and developing of entire rolls of exposed film — almost like ordinary 35mm photography.

If you are using a roll film adaptor for the Schmidt, there is not enough space to insert a sheet of scratch-prevention paper. The best approach is to smooth away all the tiny burrs that could cause scratches. Use very fine emery cloth to polish the inside corners of the plateholder where the film passes through it. Remove any roughness you can feel, however slight. Wash the plateholder thoroughly and blow it dry to get rid of all remaining dust and grit.

By the way, if you are using one of the factory-supplied roll film adaptors, double check to see that the adaptor is securely attached and square on the plateholder. If the adaptor is even slightly tipped, the plateholder may not sit properly on its magnetic button inside the Schmidt, and parts of the negative will be out of focus. It always happens just when you think your Schmidt is finally trained.

Developing 35mm Schmidt Film

Developing chips of 35mm film is a hassle. Because the chips are so small and flexible, they tend to flip off a conventional stainless steel or plastic developing reel and slosh around loose inside the tank. The result is uneven development or ruined film.

The best solution is fabricating a tiny film chip holder from Plexiglas to fit into a light-tight stainless steel developing tank.

The holder should accept approximately two dozen chips, bend them to a 1-inch radius to keep them from flexing out of place, and allow photographic solutions to flow freely around the chips.

Handling and developing roll film from a Schmidt camera is no different than ordinary 35mm darkroom photography. Of course, the exposures won't be spaced uniformly along the roll, but that leaves you space to write photo data between the frames. A fine-tip technical pen works well for this. (Be careful not to spatter ink on your negatives.)

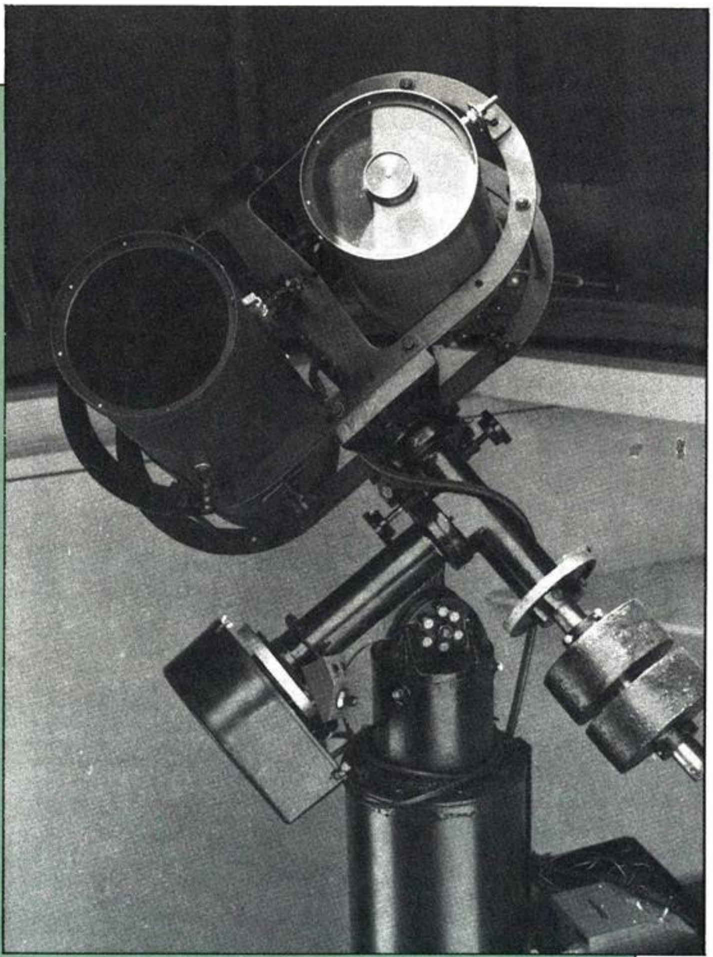
To handle developed film chips from your Schmidt camera safely and conveniently, mount the chips in plastic 35mm slide mounts and write the photo data on the mount. To make prints from a negative, use a carrier in your photographic enlarger designed to hold slides.

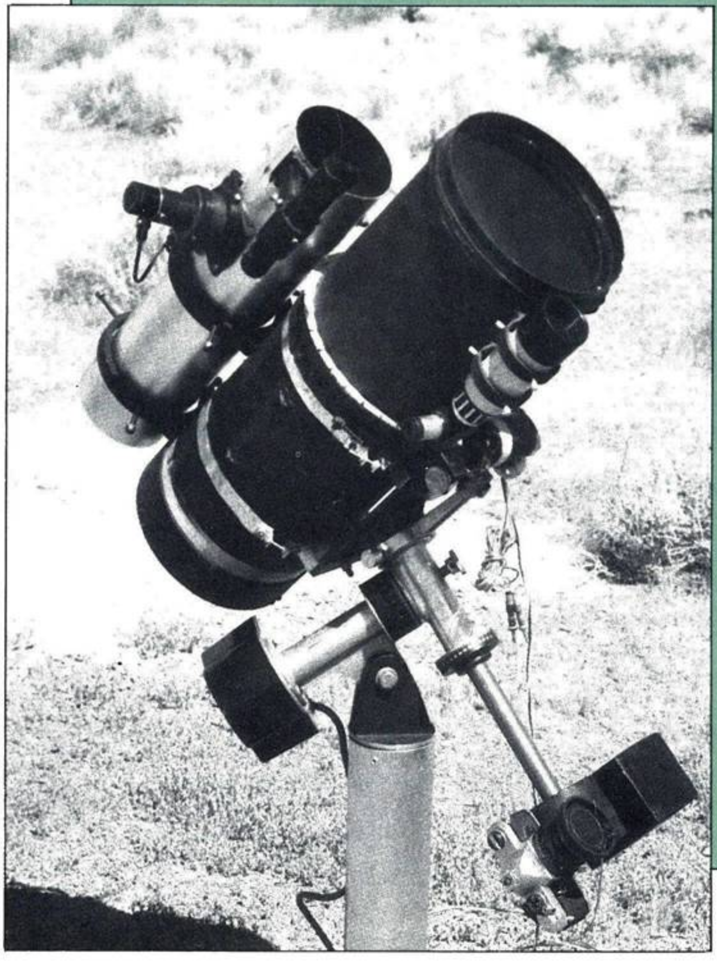
Photography with Filters

Schmidt cameras are fast — f/1.5 to f/2.6 — so there's enough light to use filters to block light that did not come from celestial objects. Photographing through filters allows much deeper exposures of sky objects, especially gaseous emission nebulae.

Special plateholders made for filter photography are available for the Schmidt. These plateholders compensate for the slight shift in focus that occurs when the converging beam of starlight passes through Wratten filters. (Most well-stocked camera stores carry Wratten gel filters, and any camera store can order one for you.) A small metal ring that snaps over the front of the film holder carries each gel filter. Filters are glued to the ring. Loading the special plateholder is just like loading the regular plateholder, except that after you have inserted the film, you must snap the filter ring onto the holder. It's a good idea to practice attaching the filter ring to the holder in daylight lest you find the filter lying on the bottom of the camera after you complete a long exposure. That's when you learn you haven't yet tamed the beast.

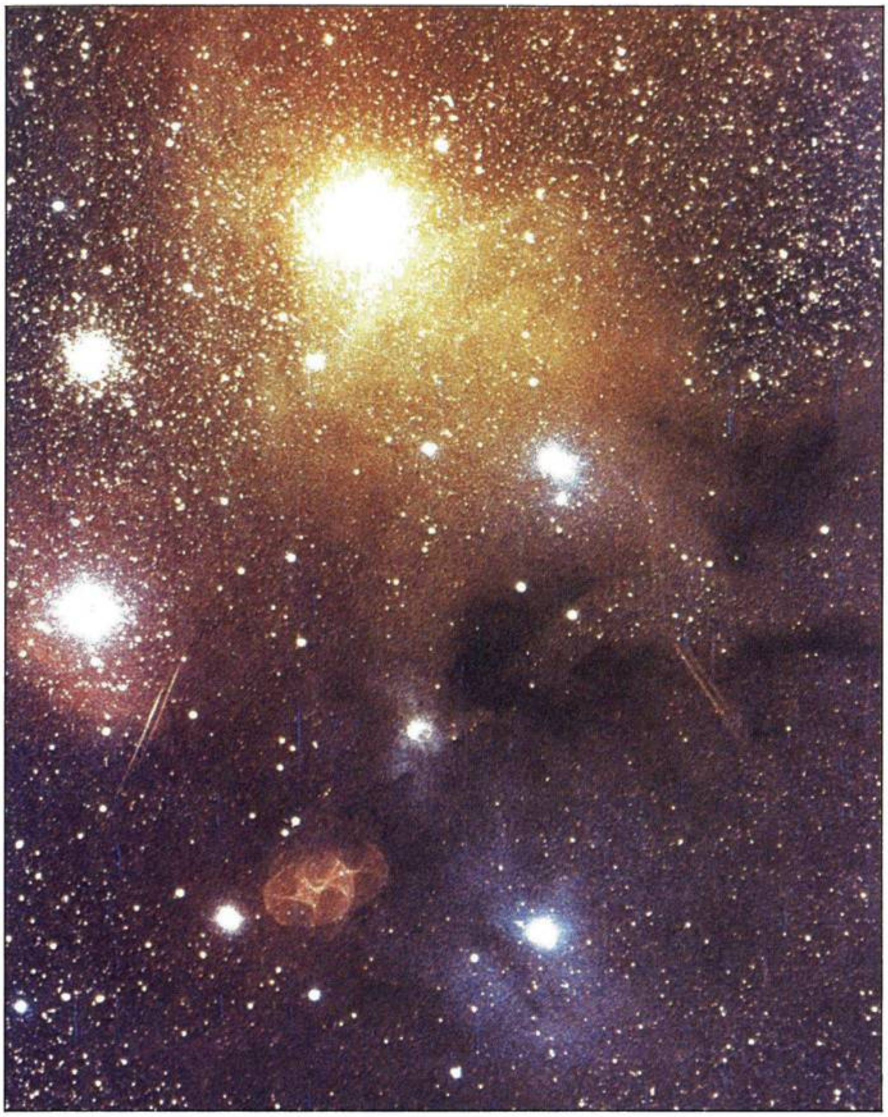
With black-and-white Kodak Technical Pan film you will get the best results with a Wratten #92 filter instead of the Wratten #25 or #29 most astrophotographers use. The Wratten #92 filter is a deeper red than the #25 or #29, so it isolates the red 656-nanometer H-alpha emission line more fully and cuts out more light pollution. A pair of scissors and a couple dabs





Top: Robert Reeves mounted his Schmidt camera side by side with his 8-inch SCT guide telescope in a theta-shaped steel frame atop a German equatorial mounting originally made for a 10-inch Newtonian reflector.

Bottom: A portable mounting made for a 6-inch Newtonian serves as Mace Hooley's Schmidt camera mounting. A piggyback 4-inch Newtonian reflector is the guide telescope. Note the camera on the counterweight.



Compositing two 30-minute exposures on Fuji R-100 film processed to a color negative enabled Mace Hooley to show the subtle colors of bright and dark nebulae in the "Antares Pentagon" region of Scorpius and Ophiuchus. The combination of high speed, wide field, and sharp imagery makes the Schmidt camera ideal for "deep" color photography.

of Super Glue are all it takes to switch to a #92 filter.

Shuttering the Schmidt

The Schmidt camera has no shutter, or rather the photographer is the shutter of a Schmidt camera. As soon as you remove the dust cap from the camera, the exposure starts. With such an advanced star camera it seems strange that the shutter mechanism is a throwback to the daguerreotype era, but that's the way it is.

Obviously you need to be guiding even before the exposure starts, but because you can't be at the guide eyepiece and pull off the cap at the same time, you have to come up with a way to open the shutter from your guide eyepiece. You can solve the shutter problem by hanging a lightweight black cloth over the front of the camera. When you're satisfied the guide star is centered, gently tug on the drape and it drops free from the front of the camera, starting the exposure. To end the exposure, simply flop the cloth over the front of the Schmidt and then put on the dust cap. It's simple and effective.

Keeping the Corrector Plate Dry

Schmidt cameras have large, thin plate glass corrector plates that are subject to dewing just like Schmidt-Cassegrain telescopes. For this reason it is best to use a dew cap on both the Schmidt camera and on the guide telescope.

A long dew cap not only prevents dew, but it also protects the camera from stray light that can fog your film and obscure the faint celestial object you want to capture. (When that happens, you may be the one acting like a wild animal.)

For even better dew protection, wrap a turn of electric heating tape around the corrector plate end of the camera. By keeping the corrector temperature above the dew point of the air, you will eliminate dewing on all but the wettest nights.

Still better, use a heated dew cap (see "Build a Heated Dew Cap for Less than $10" by Harry Hammond, Equipment Atlas, November 1987). This double-whammy device will keep the dew off the corrector and stray light out of the camera.

Keep the Film Dry Too!

High humidity causes the corrector plate to fog, but few amateurs realize high humidity inside the camera also causes problems. Hypered Technical Pan film suffers chemical fogging when exposed to high moisture levels, which can ruin your exposure.

To keep the humidity from ruining your exposures, try rigging a system to purge water vapor from your Schmidt by flooding the inside of the camera with dry gas. With automotive brass fittings and hose you can pipe dry gas into your Schmidt and push out the humidity-laden air during the exposure.

Drill two small holes into the skin of the Schmidt, one just above the mirror, the other just below the corrector. Install bulkhead fittings in these holes and attach hoses leading from the camera to a dry gas supply. You can use dry nitrogen for this. Although it comes in heavy cylinders, they are not expensive and are readily available.

Bleed the dry nitrogen into the Schmidt for several minutes at the beginning of each exposure. This gently forces the moist air out of the camera body. If your exposures are often 30 to 40 minutes long, a little moisture in the camera during the first few minutes of purging does not bother the film. The idea is not to desiccate the inside of the Schmidt but to lower the humidity to 10 to 20 percent, which is tolerable to the film.

Because expanding gas gets cold, bleed it into the camera slowly. If you bleed it in too rapidly, the cold gas will cool the corrector plate and thus aggravate the dewing problem.

Schmidt Camera Mounts

The manufacturers of Schmidt cameras recommend mounting the cameras piggyback atop a telescope that costs five times what a Schmidt costs, and the Schmidt isn't exactly cheap. What's an impoverished astrophotographer to do? Well, necessity is the mother of invention. We mounted our Schmidt cameras on German equatorial mounts with parts we made ourselves. These mounts show that a little imagination can go a long way when it comes to solving potentially expensive problems in mounting and guiding a powerful astrocamera.

Reeves' Double-Barrel Shotgun Mount

My Schmidt camera shares a mounting with an 8-inch f/10 SCT. The instruments are tandem-mounted in a fabricated steel framework shaped like a big Greek letter theta (Θ). The combined unit tracks the sky atop a German equatorial mounting made for an Optical Craftsman 10-inch reflector. I had remounted the reflector in a Dobsonian mounting, which left the equatorial mount free for a new use.

Three rubber-tipped centering bolts support and align the Schmidt camera at the front and two anchor it at the rear using the fork-mounting pads; two bolts support the SCT at each end. The wide field of the Schmidt virtually guarantees that I can find a guide star near the center of the field, and the light grasp of the 8-inch instrument gives me lots of candidates.

If your workshop is not equipped for metalworking, there is no reason the double-barrel mount couldn't be made of plywood. Just be sure to make the mount solid: use two layers of 3/4-inch plywood glued back to back for each theta-shaped piece and with a double thickness for the base plate and brace it well throughout.

One benefit of the double-barrel approach is that the mount carries several wide-field 35mm cameras on top. By putting each camera on a swivel ball head, I can shoot several different areas of the sky while guiding a Schmidt shot.

As an astrophotographer, I really like this dual mounting. The camera is lower than it would be if it were piggybacked atop another telescope. This makes guiding easier and handling and loading the film into the Schmidt is also much easier because I do not have to reach so far.

Hooley's Over-and-Under Mount

I had used a 6-inch f/5 reflector and its German equatorial mounting for several years, so when it came time to mount my Schmidt camera, using the Schmidt on this lightweight, seemingly undersized mount seemed logical. With a mount so light I realized I would have to keep the guidescope light as well.

I cut the original mounting rings that had held the 6-inch tube assembly and added straps to reach around the larger diameter 8-inch Schmidt camera. This arrangement allows me to rotate the Schmidt for precise composition of large objects on the film frame. I loosen the straps to rotate the Schmidt about its axis and then tighten the straps again to secure the tube firmly to the mounting.

Originally I used a 60mm refractor as a guide telescope. The guidescope rode piggyback on the Schmidt camera — a slightly unusual arrangement that works well. Although the 60mm scope was adequate, I have recently replaced it with a 4-inch f/4 Newtonian reflector. The larger aperture of the reflector gives me twice as many potential guide stars.

Because the counterweights supplied with the original 6-inch reflector were not heavy enough for my photo rig, I mounted the cameras I formerly carried piggyback on the counterweight. The cameras bolt directly to the counterweight and provide not only the weight needed to balance the system but the bonus of well-guided wide-field shots.

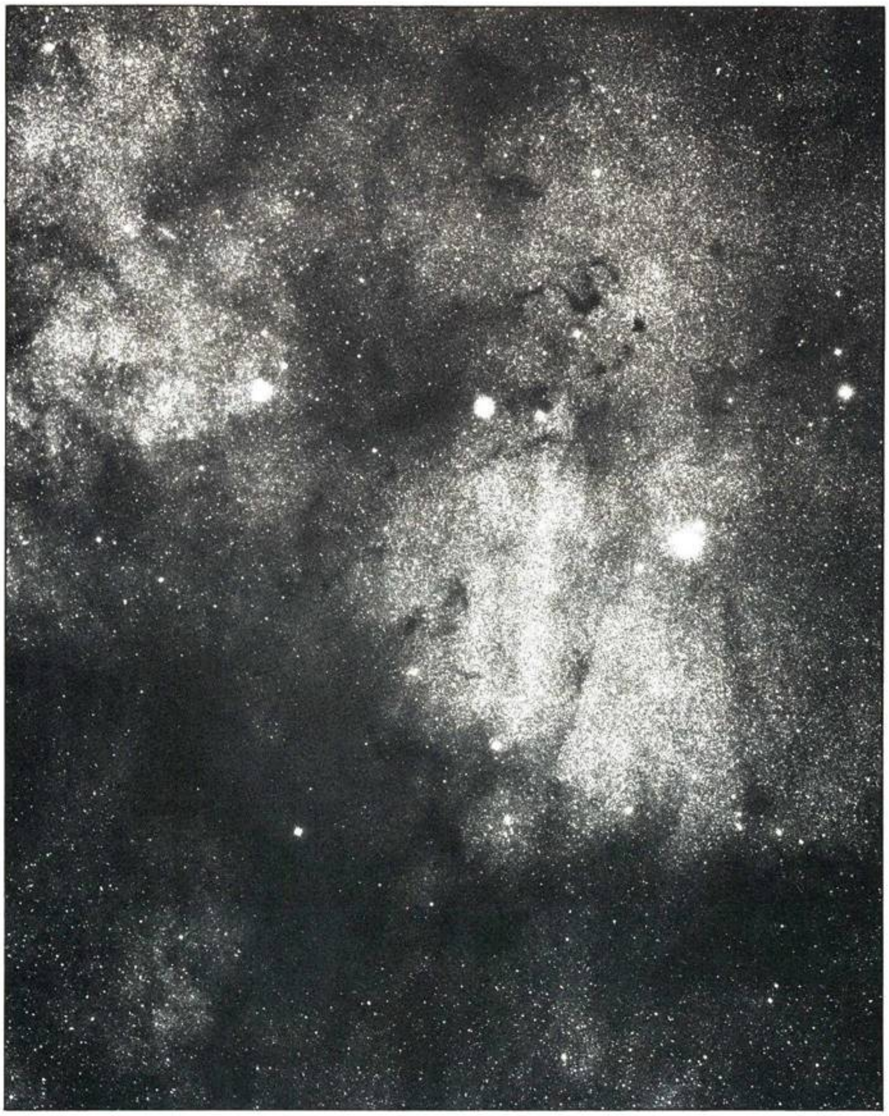
The only drawback with the German equatorial mount occurs when I want to track an object across the zenith. As with any German equatorial, the camera hits the right ascension drive housing or pier when the object crosses the celestial meridian. This is seldom a problem with exposures shorter than two hours.

When I discovered that the original declination motor and gear on the mount were too small to move my newly installed astrophoto rig, I bought a surplus Xerox copier motor and installed it on a bracket in place of the original motor. The new motor has enough torque for declination slow-motion guiding.

The marriage of the 8-inch Schmidt camera and the standard 6-inch mount has worked out well. As my photographic results demonstrate, an inexpensive mounting can provide professional-looking results. There must be zillions of these lightweight equatorial mountings lying around unused all around the country. Someone contemplating astrophotography should not rule them out; when pressed into service they can perform surprisingly well.

Precision Guiding for Precision Optics

Because Schmidt cameras are capable of well over 1,000 line-pairs per millimeter resolution, extremely small star images are formed. Because of the extremely sharp images and high resolution, the highest possible power is necessary for guiding. Use the highest magnification you can. If you can keep the star within the double cross hair box in your guide eyepiece, you will get perfect round star images.



E. E. Barnard's famous S Nebula lies just north of the star Theta (θ) Ophiuchi in this 30-minute exposure on hypersensitized Kodak Technical Pan film. Note the delicate veils of dark nebulosity that overlie the entire field. Paul Roques made this picture with a 4-inch f/2.64 Schmidt camera made by Meade Instruments Corporation.

Practice Makes Perfect

Practice all of the operating routines for your Schmidt in daylight. Master the camera's intricacies and develop some little tricks to overcome its quirks. Although taming a Schmidt camera requires a little patience, once you show the camera who's boss it will provide you with countless thrills as you use it to photographically discover the universe.

Robert Reeves' most recent contribution to ASTRONOMY was "Globetrotting Observer Paul Maley: Chasing the Fleeting Moment," published in November 1987. Mace Hooley shoots his pictures under the clear skies of Arizona and specializes in very deep color astrophotography. These two astrophotographers, skilled in the use of the Schmidt camera, joined forces to share their techniques with ASTRONOMY readers.

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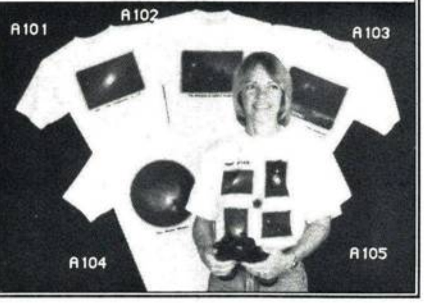

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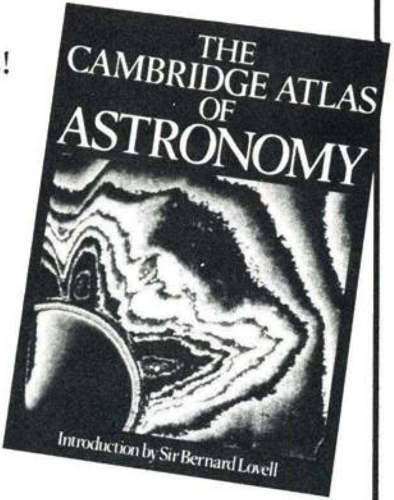

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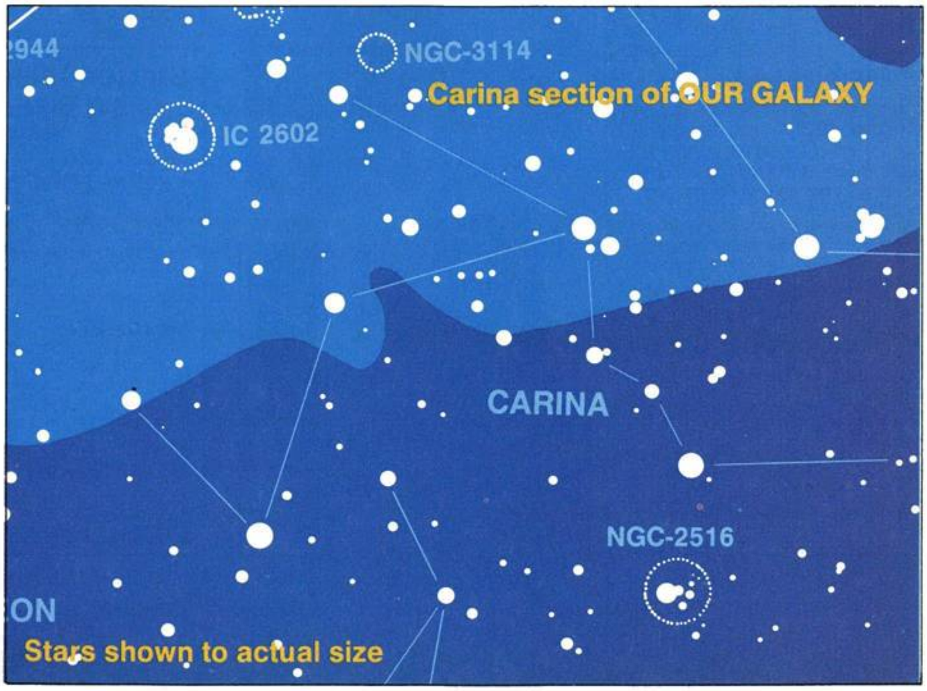

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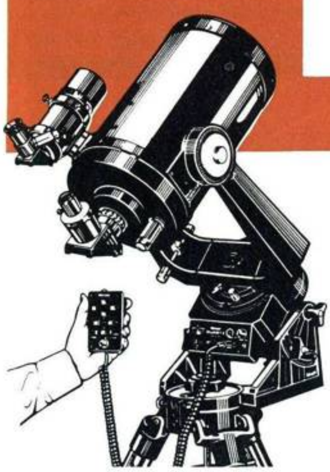

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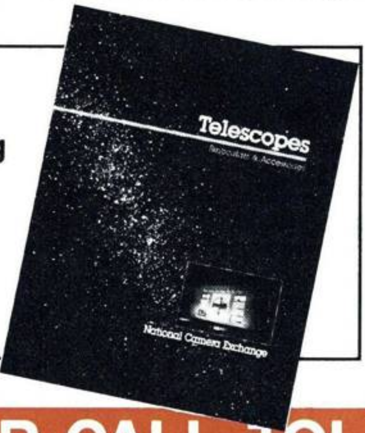

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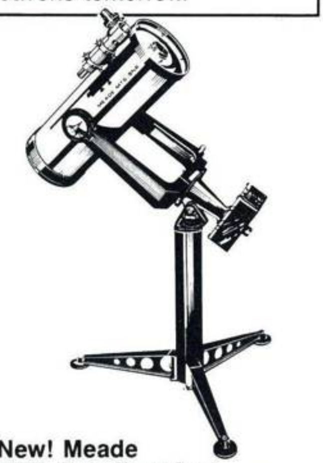

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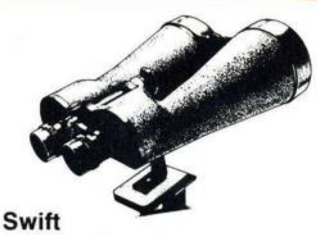

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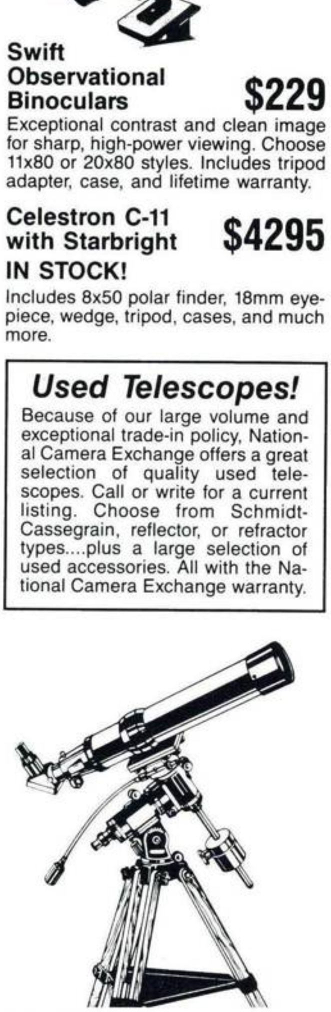

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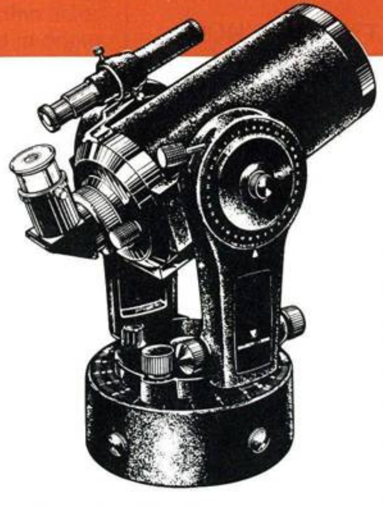

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AstroNews

Arch girders, the main structural supports for the dome of the W. M. Keck Observatory, were in place atop 14,000-foot Mauna Kea in Hawaii in August 1987. When the Keck Telescope begins operation in 1991, its thirty-six hexagonal mirrors — the equivalent of a mirror 33 feet across — will make it the world's largest instrument for optical and infrared astronomy. By the end of this year the assembly and testing of the dome should be complete. The dome will then sit empty for six to eight months until the telescope mount is brought to Hawaii for installation. The Keck Observatory is a joint project of the California Institute of Technology and the University of California. California Association for Research in Astronomy photo.

Polymer Found in Comet Halley

Comet Halley apparently harbors molecules of the polymer polyoxymethylene. Investigators using data obtained by the Positive Ion Cluster Composition Analyzer experiment (PICCA) that flew on the *Giotto* spacecraft found fragments of the polymer in mass spectra obtained when the spacecraft flew through the comet's inner coma. If this complex molecule originated in the solar nebula 5 billion years ago, as the scientists who made the discovery suspect it did, the discovery may provide clues to the origin of the solar system.

The PICCA instrument detected peaks in the distribution of molecular mass at 45, 61, 75, 91, 105, and 121 atomic mass units. According to the researchers, the only likely explanation for this mass spectrum is polyoxymethylene (POM), a chain of $-H_2CO-$ units. (H_2CO is the chemical formula for formaldehyde, so POM is sometimes called polymerized formaldehyde.)

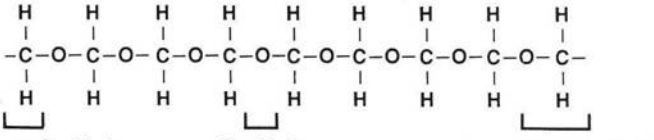
University of California at Berkeley, Southwest Research Institute, and Max-Planck-Institut fur Aeronomie scientists note that POM fragments into units of $-H_2C-$ and $-O-$ with molecular weights of 14 and 16 atomic mass units, respectively. Thus the pattern of peaks in the mass spectrum with alternating differences of 14 and 16 mass units represent short chains of POM.

The presence of POM helps explain the extreme darkness of Halley's nucleus and the distribution of grain sizes observed near the nucleus. POM molecules attach themselves readily to grains of graphite and silicates, creating whiskerlike protrusions that trap light. These also tend to "glue" individual grains into grain clusters. The so-called CHON particles flowing outward from Comet Halley's nucleus were largest close to the nucleus and smaller farther away (see "What Have We Learned from Halley's Comet?" by Richard Berry and Richard Talcott, September 1986 and "Search for the Primitive" by Richard Berry, June 1987).

The polymer could have formed in the interstellar medium and could have been included in the cometary ices when the comet formed, or it could have formed near the comet's surface as cosmic rays bombarded small organic molecules in its ices. Because Comet Halley still releases POM after numerous trips around the Sun, the researchers believe they observed primordial polyoxymethylene that was incorporated into the comet rather than a surface layer that would have boiled off long ago.

If they are correct, then POM must have been present in the solar nebula when the Sun and the planets were formed 4 billion to 5 billion years ago. POM, therefore, should be an important tracer for the early history of the solar system. The presence of POM in the solar nebula also means that POM should exist in interstellar clouds.

Polyoxymethylene Polymer



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Amino Acids from Space

An analysis of the hydrogen in amino acids found in the Murchison Meteorite that fell in Australia in 1969 has revealed the presence of deuterium, a rare hydrogen isotope. According to scientists from the California Institute of Technology and Arizona State University, the finding strongly indicates that some amino acids in meteorites are extraterrestrial in origin and are not added by contamination after the meteorites enter Earth's atmosphere.

Determining the extraterrestrial origin of amino acids in meteorites is significant because these organic compounds — the basic building blocks of life — may have been carried to Earth by meteorites, seeding our planet for the evolution of life. Although scientists have known about the existence of amino acids in meteorites for several decades, methods for ascertaining which amino acids are unique to the meteorite and which are added by contamination have not always been conclusive.

In addition to deuterium, the research team found an unusually high concentration of nitrogen-15, a rare isotope of nitrogen, in the amino acids they analyzed. Deuterium was also found in carboxylic acids — a class of organic compounds —in the meteorite fragments.

Deuterium is very rare on Earth, forming 0.0149 percent of the hydrogen in naturally occurring hydrogen compounds, such as ocean water. Because these isotopes are rare, it is unlikely they could have become concentrated to the abundances found in the meteorite fragments merely from exposure to a terrestrial environment. The researchers believe the organic compounds may have originated in interstellar clouds, where such deuterium enrichment is common. Radio astronomers first detected high concentrations of deuterium atoms in interstellar clouds in the early 1970s.

So far researchers have found fifty-five amino acids in the Murchison Meteorite. Of these, eight are normal constituents of protein and eleven others are known to occur in biological systems. An isotopic analysis may determine which, if any, of the remaining amino acids are unique to meteorites.

Additional evidence for the interstellar origin of amino acids in meteorites comes from the isotopic analysis of the hydrogen and nitrogen contained in molecules of organic matter in meteorites. Organic matter in meteorites is in the form of large, complex molecules composed mostly of carbon, hydrogen, oxygen, and nitrogen. When this material is heated to high temperatures, it decomposes and produces hydrogen and nitrogen compounds with unusually high concentrations of deuterium and nitrogen-15.

Samuel Epstein, a member of the research team at Caltech, says the possibility of an extraterrestrial origin for the amino acids should encourage efforts to

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study the original source of these amino acids on early Earth.

"The importance of these amino acids to the original building blocks of life," Epstein says, "might be investigated by searching for these unusual isotopic materials in the oldest sedimentary rocks on Earth."

Will the Milky Way Become a Quasar?

The Milky Way Galaxy contains a black hole in its center that someday could become a quasar, a powerful source of x-rays and other radiation, according to Mitchell C. Begelman of the Joint Institute for Laboratory Astrophysics at the University of Colorado at Boulder. Most galaxies contain black holes and will likely produce quasars in their nuclei, according to most studies of galactic evolution. If this process occurs in the Milky Way, the quasar will rock the galaxy and produce a "scar" that would last for billions of years.

If a quasar should occur in the Milky Way's future, our Galaxy's nucleus would produce primarily x-ray energy equaling about 10 trillion times that of the Sun. This would cause changes in the surrounding interstellar medium, as clouds of heated interstellar gas simply blew away or evaporated. This in turn would prevent new stars from forming and would accelerate the evolution of the Galaxy as a whole.

Fortunately, Begelman believes the Milky Way's black hole is at present too small to produce intense x-ray heating in our part of the Galaxy, some 8 to 10 kiloparsecs out from the center. Aside from speculating further about the Galaxy's future, astronomers now look forward to using the Hubble Space Telescope to peer deeper into the Milky Way's center, searching for more clues about possible high-energy activity.

Space Technology Guards Historic U.S. Documents

The electronic eyes that will look at Jupiter in the 1990s are the same eyes that will watch the two hundred-year-old U.S. Constitution for signs of deterioration. The charge-coupled device (CCD) technology developed by the Jet Propulsion Laboratory to take planetary pictures on unmanned missions will monitor the condition of the Constitution, the Declaration of Independence, and the Bill of Rights in the National Archives.

Called the Charters of Freedom Monitoring System, the National Archives system creates and stores detailed electronic images of the historic documents. By comparing the electronic images over time, conservators will be able to detect any changes in contrast, shape, and degradation of parchment pages, so preservation methods can be applied — before the human eye could detect any deterioration.

The sensitivity of the CCD system provides images five to ten times better than the human eye could see. The system "sees" one narrow line at a time. Each line is then divided into 1,024 picture-element dots called pixels, which are exposed and stored. The system also controls the illumination, position, vibration, and temperature, without affecting the condition of the documents, to ensure that each image is repeated identically.

Europe Back in Space with *Ariane* Launch

The European Space Agency's *Ariane 3* launcher resumed normal flight operations on September 15, 1987, when it successfully launched two communications satellites into geostationary orbit. This was the first launch since the failure of an *Ariane 2*'s third-stage rocket motor grounded the launcher in May 1986.

The redesign and testing of the new third-stage motor put *Ariane* behind schedule in the launching of commercial satellites. It will need to carry out eight or nine launches a year until 1990 to make up for lost time.

The two satellites, *ECS4* and *AUSSAT K3*, were launched from the French Guiana Space Center in South America. The European satellite *ECS4* will be used for international telephone, business, and television communications, while *AUSSAT K3* will provide a voice and data link for Australian air traffic controllers.

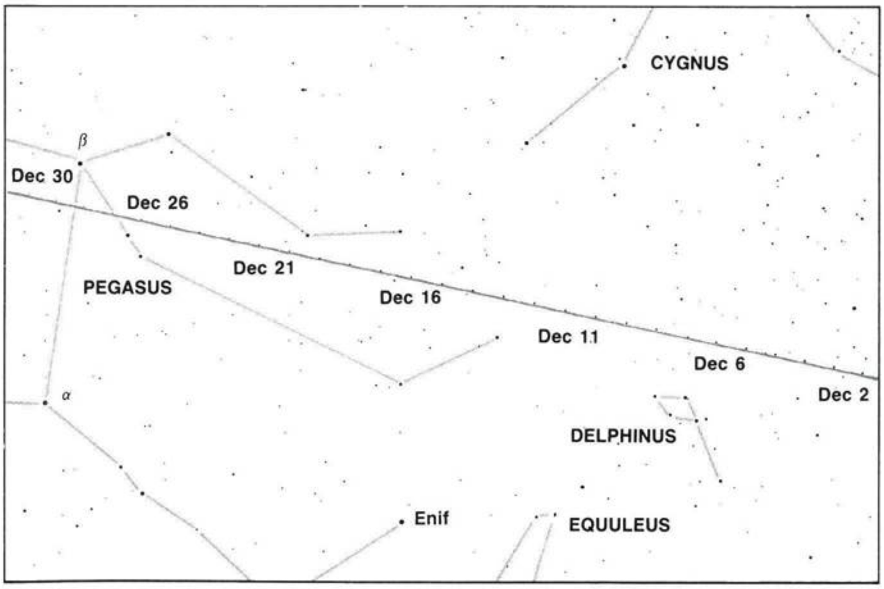
Redshift Theory May Alter Cosmic Distances

A new theory concerning the behavior of light may radically alter the way astronomers use redshifts to determine distances. The theory, proposed by Emil Wolf of the University of Rochester, states that the spectrum of light can change as the light travels over great distances through space. This contradicts an important assumption physicists rely on to study the properties of light: that the spectral characteristics of light are constant. If the new theory is true, it may have drastic consequences on interpreting distant astronomical objects like quasars by using their spectral signatures.

In a paper published in *Nature* (March 26, 1987), Wolf shows the characteristics of light energy can change as the light travels, so a viewer at a great distance from the source can't be sure the light he sees has the same properties as the light had when it left the source.

Wolf's theory is based on work he conducted in the specialized field of physics called partial coherence theory. First presented in 1959 when Wolf collaborated with physicist Max Born, the coherence theory describes the behavior of light in various states between order and randomness. For example, light generated by a laser is in a state of order, while light generated by an incandescent bulb is in a state of randomness. Coherence theory also describes how light oscillations at different distances from a source resemble one another.

In March 1986 Wolf added a new optical law to coherence theory and called it



Comet Bradfield remains an easy binocular object throughout December as it slowly fades in brightness but climbs higher in the early evening sky. On December 1, Bradfield lies in the rich Milky Way starfields of northeast Aquila at a predicted magnitude of 5.1 and an altitude over 40°, an hour after sunset. In quick succession the comet traverses Sagitta, Delphinus, and Vulpecula (where it reaches its closest approach to Earth on December 12) and then moves into Pegasus for the last half of December. On the 31st Bradfield should shine at magnitude 6.5, and it will be close to 65° above the southwest horizon an hour after sunset.

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the scaling law. This law explains why light energy is generally constant as it travels away from its source. Experiments have shown that the scaling law can predict how distant light spectra remain identical — or change — with the source spectra.

One of the implications of the scaling law is Wolf's new proposal of the cause for redshifts, which he calls source correlation. Source correlation refers to the related order among individual atoms that generate the light source and how well their "ripples," or fluctuations, correspond to one another inside the source. This means the spectral distribution of light energy not only depends on the light's degree of order as it travels through space but on its correlation at the source.

As an analogy, if two stones were dropped into a pond simultaneously, the waves would ripple in an orderly fashion. But if the stones were dropped randomly, the ripples would become incoherent and lack any correlation. According to Wolf, this is similar to what occurs in the propagation of light energy.

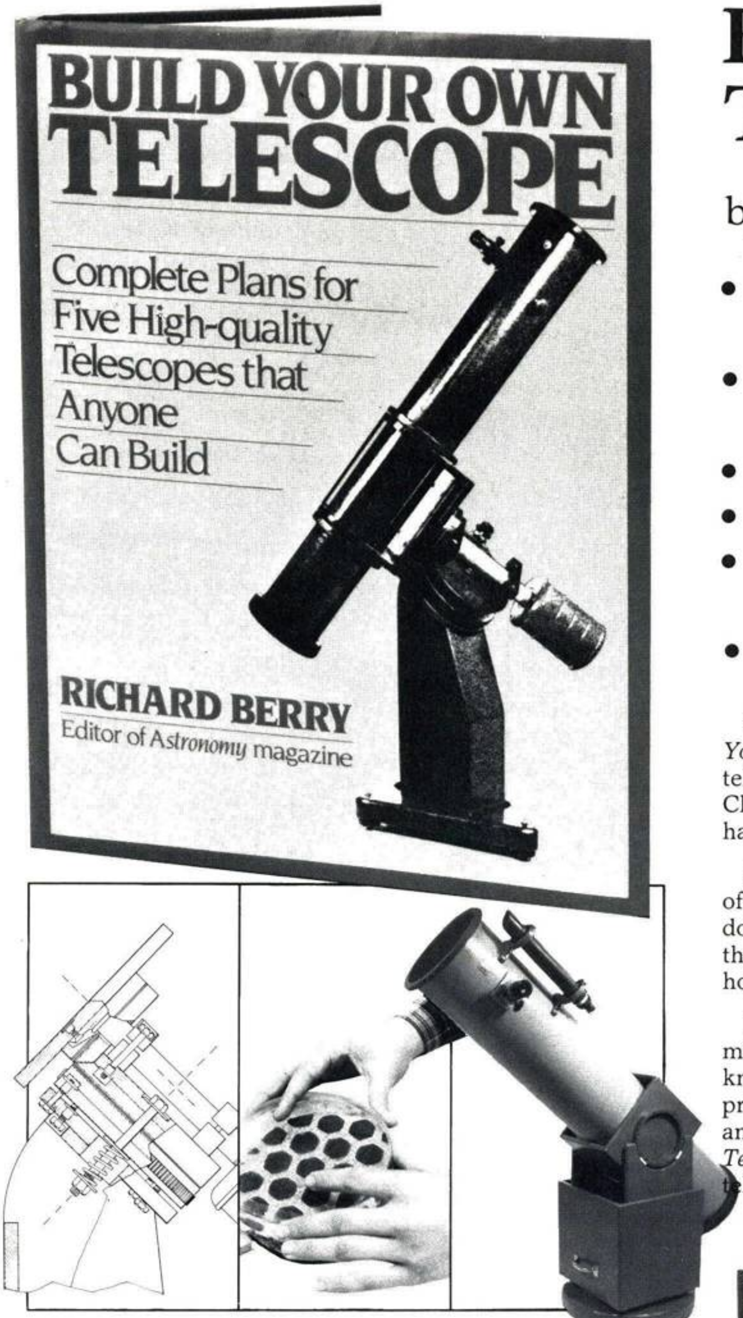
The disordered ripples of light energy produced in some stars can generate equally disordered energy wavelengths. The result is that observed redshifts may not correspond to the velocities of objects in the universe and thus to the distances of distant objects. "Source correlation suggests that estimates of distances of quasars may need to be reinterpreted based on this new information," according to Wolf.

If experiments continue to support Wolf's theory, astronomers may have to re-evaluate much of their fundamental information on distant objects in the cosmos.

In June 1987 three University of Rochester scientists used sound waves to confirm the theory experimentally. They could do this because both light and sound act as wave phenomena. Mark F. Bocko, David H. Douglass, and Robert S. Knox constructed a sound source consisting of two commercial loudspeakers. Because of the way the sound waves interacted, the researchers concluded Wolf's theory holds true (in an experimental test) under carefully controlled conditions.

Where Are You, Perseus Flasher?

For two years amateur astronomers have reported mysterious bright flashes of light in the constellation Perseus. In 1986 a group of Canadian amateurs published a paper in *Astrophysical Journal Letters* (August 1, 1986) that proposed their eight visual sightings and single photograph of these events constituted evidence of optical flashes from a gamma-ray burster. Two new research studies, however, conclude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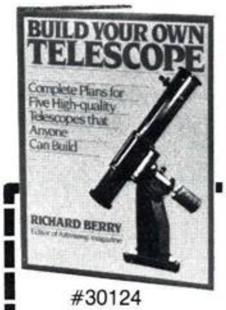
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that most, if not all of the mysterious flashes in Perseus are caused by nonastronomical events.

A group of astronomers centered at NASA's Goddard Space Flight Center have published a paper that just falls short of resolving this issue. Goddard's Bradley E. Schaefer and ten other astronomers compiled information on 3,287.9 hours of monitoring the Perseus Flasher region and found that not a single event occurred during this time. Moreover, the scientists report that flashes caused by glints of sunlight reflected by satellites do occur in other parts of the sky. Of the sightings reported by the Canadians, Schaefer and colleagues determined one was a Taurid point meteor, the positions of four observations were inconsistent with the photographed position, one of the sightings could not have occurred because the Sun was only 5° below the horizon, and other inconsistencies. The astronomers also identified satellites that could account for several of the observed events.

Using the 30-inch telescope at the University of Washington's Manastash Ridge Observatory, astronomers Peter Garnavich and Scott Temple conducted a photographic survey of the region where the Canadians photographed a flash in 1985. Garnavich and Scott made twenty-nine plates between October 8 and 24, 1986, and found no flashes. Together the twenty-nine plates totaled thirty-eight hours of observing time; based on the Canadians' calculations one flash should occur on average every twelve hours. Because they found nothing, Garnavich and Temple conclude an astronomical origin for the flashes in Perseus is "doubtful."

The investigation of the mystery flashes in Perseus will probably continue for some time, though Schaefer says "most of the flashes are caused by glints of reflected sunlight off of flat surfaces on artificial Earth satellites."

ASTRONOMY
AstroCalendar

November 10-13
19th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society, Pasadena, California. Contact: Kevin H. Baines, Local Arrangements Chairman. Phone: (818) 354-0481.

November 19
2nd Annual Hubble Lecture ("Quasars, Black Holes, and the Fate of the Universe" by Martin J. Rees), The Johns Hopkins University, Baltimore, Maryland, at 8 p.m. Contact: L. Fournier, Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218. Phone: (301) 338-4714.

December 21-22
International Seminar on Ancient Astronomies (sponsored by the B. M. Birla Planetarium), Hyderabad, India. Contact: B. G. Sidharth, Director, B. M. Birla Planetarium, Adarsh Nagar, Hyderabad, 500 463, India.

January 10-14, 1988
171st Meeting of the American Astronomical Society (professional meeting sponsored by the University of Texas at Austin and McDonald Observatory), Austin, Texas. Contact: American Astronomical Society, 2000 Florida Avenue, NW, Suite 300, Washington, DC 20009.

January 16
3rd Annual Astronomy Day (sponsored by Patterson Planetarium and Callaway Gardens), Callaway Gardens outside Columbus, Georgia. Contact: Carole Rutland Groce, Patterson Planetarium, 2900 Woodruff Farm Road, Columbus, Georgia 31907. Phone: (404) 568-1730.

January 16-17
Astronomy Weekend (telescope fair, observing, exhibits, sponsored by the Louisville Astronomical Society and the Louisville Museum of History and Science), Louisville, Kentucky. Contact: Alan Goldstein, Museum of History and Science, 727 West Main Street, Louisville, KY 40202. Phone: (502) 589-4584.

January 16-18
Stardate '88 (observers convention), Cape Egmont Observatory, New Plymouth, North Island, New Zealand. Contact: David Coppart, P.O. Box 811, Whangarel, New Zealand.

February 18-21
IAPPP Symposium: New Generation Small Telescopes, Lazy K Bar Ranch, Tucson, Arizona. Contact: Russell M. Genet, Fairborne Observatory, 1357 North 91st Place, Mesa, AZ 85207. Phone: (602) 986-2828, (602) 297-0702 for reservations.

February 18-21
4th Annual Winter Star Party (sponsored by the Southern Cross Astronomical Society), Florida Keys, Florida. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

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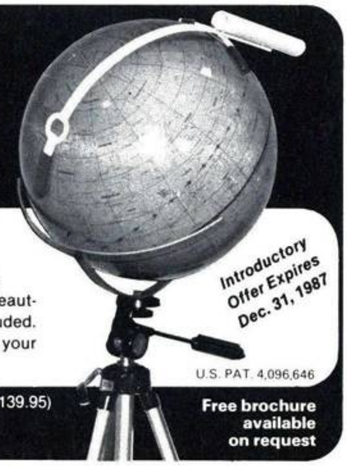

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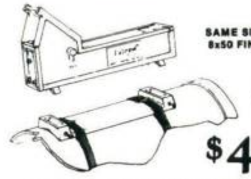

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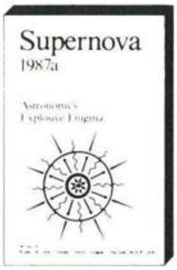

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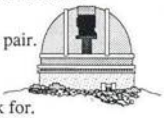

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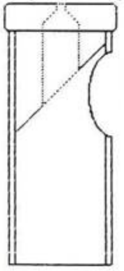

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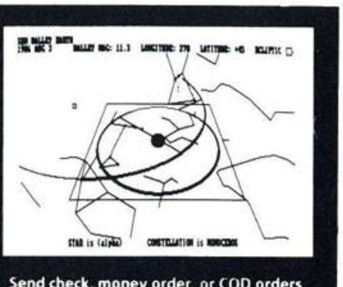

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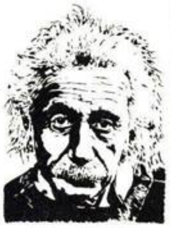

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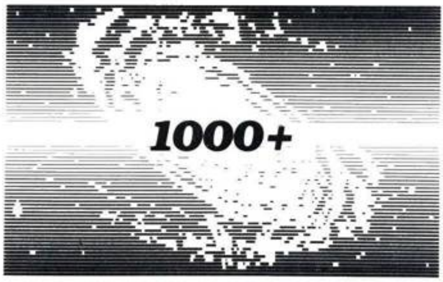

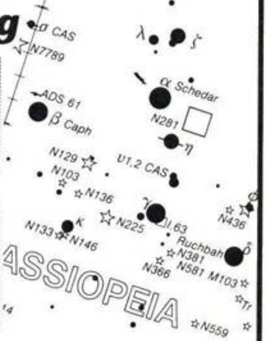

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STANDARD FEATURES & FACTORY-SPECIFIED EQUIPMENT, 2120/LX3:

Complete f/10 telescope tube assembly (10" aperture, 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity (multi-layer over-coated) mirrors; ultra-smooth anti-backlash focus mechanism; large 8x50mm illuminated-reticle polar-alignment viewfinder; 1.25" visual back (eyepiece holder); 1.25" prism-type star diagonal, anti-reflection coated; Series 4000 Super Plossl eyepiece, 1.25"; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; QUARTZ MICRO-ELECTRONIC SIDEREAL-RATE DRIVE SYSTEM and ultra-precision "LX" worm-drive gearing built into telescope drive base; POWER CONTROL PANEL (also built into drive base) WITH CONTROLS, INDICATORS and CONNECTORS for various accessory and auxiliary electronic equipment (includes input power connector; red LED indicator light; "Internal-External" drive control switch; brightness adjustment knob for *optional* illuminated-reticle guiding eyepiece; power jacks for: (1) the "Drive Control" hand-control unit ["Electronic Command Center"], (2) *optional* declination control motor, (3) *optional* LED map light, and (4) *optional* illuminated-reticle guiding eyepiece); ELECTRONIC COMMAND CENTER hand-control unit with: (a) "Quartz" (fixed) or "Manual" (variable) drive rate control switch, (b) variable (manual) drive-rate control knob (Lunar, Solar, Sidereal, etc.), (c) N-E-S-W drive correction control buttons, and coil-cord and plug for connection to telescope's Power Control Panel; AC power adapter with 25 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level and magnetic compass; ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; instruction manual; limited lifetime warranty.

2120/LX3 MCOG (List: $5,000) **$1,779.95**

FREE FREIGHT! (UPS Ground) for the LX3 shown above

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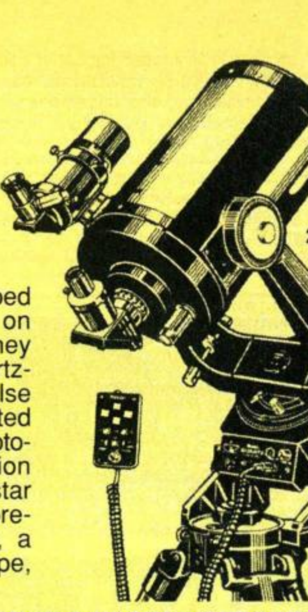

Shown: 2080/LX5 MCOG

STANDARD FEATURES & FACTORY-SPECIFIED

Complete f/10 telescope tube assembly (8" or 10" aperture, 2,000mm or 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity (multi-layer over-coated) mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated-reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 26mm Super Plossl eyepiece, 1.25" (77x or 96x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; DIGITAL QUARTZ MICRO-ELECTRONIC SIDEREAL-RATE PULSE-MOTOR DRIVE SYSTEM and ultra-precision "LX" worm-drive gearing built into telescope drive base; POWER CONTROL PANEL (also built into drive base) WITH CONTROLS, INDICATORS and CONNECTORS for various accessory and auxiliary electronic equipment (includes input power connector; "on/off" switch, red LED indicator light; milliammeter to show current draw; "N/S" hemisphere switch; brightness adjustment knob for *optional* illuminated-reticle guiding eyepiece; power jacks for: (1) the "Drive Control" hand-control unit ["Electronic Command Center"], (2) *optional* declination control motor, (3) *optional* electric focuser, and (4) *optional* illuminated-reticle guiding eyepiece); ELECTRONIC COMMAND CENTER hand-control unit with: (a) "Quartz" (fixed) or "Manual" (variable) drive rate control switch, (b) variable (manual) drive-rate control knob (Lunar, Solar, Sidereal, etc.), (c) correction/scanning rate switch (2x & 8x the base drive rate), (d) red LED map-light, (e) map-light control button, (f) control buttons for *optional* electric focuser, (g) N-E-S-W drive correction control buttons, and coilcord and plug for connection to telescope's Power Control Panel; AC power adapter with 25 ft. cord; DC battery-pack *(batteries not included)* with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level, magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; audio cassette instructions on set-up and applications; instruction manual; limited lifetime warranty.

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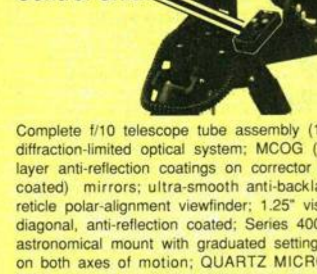
2120/LX5 MCOG (List: $5,200) **$1,959.95**

FREE FREIGHT! (UPS Ground) for the LX5's shown

Meade 2045 & 2045/LX3



Shown: Mod. 2045

Camera & T-Adapter for illustration purposes

Complete f/10 telescope tube assembly (4.0"A, 1,000mmF), with certified diffraction-limited optical system; high-transmission anti-reflection coatings on corrector plate; ultra-smooth anti-back-lash focus mechanism; 5x24mm coated achromatic finderscope; 1.25" prism-type star diagonal, coated; two 1.25" coated eyepieces (40x & 111x); rugged dual-fork astro mount, with frequency-controlled electric tracking motor built into base; graduated setting circles, manual positioning controls & clutches on both axes of motion; tabletop tripod legs (adjustable for latitude); dust covers; power cord; foam-lined metal-clad carrying case; instructions; limited lifetime warranty. **LX3 version has, in addition**, multi-coated corrector plate; LX3 QUARTZ MICRO-ELECTRONIC SIDEREAL RATE DRIVE SYSTEM, POWER CONTROL PANEL & DUAL DRIVE MOTORS, all built into drive base.

This unit can readily double as a high-quality terrestrial spotting scope or telephoto camera lens, making it an extremely versatile instrument. Many useful accessories and attachments are available for it.

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Accessories for Meade Telescopes

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Electric Focuser, Mod. 1200, for LX3's	(List: $ 250.00)	**$159.95**
Electric Focuser, Mod. 1200A, for LX5's	(List: $ 230.00)	**$149.95**
Electric Declination Motor, Mod. 38A, for 2045/LX3	(List: $ 150.00)	**$ 99.95**
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Electric Declination Motor, Mod. 39, for LX5's	(List: $ 160.00)	**$109.95**
LensShade-DewShield, Mod. 712, for 2080	(List: $ 90.00)	**$ 62.95**
LensShade-DewShield, Mod. 710, for 2120	(List: $ 140.00)	**$ 97.95**
Accessory Tray-Shelf for Field Tripod, for 2080 or 2120	(List: $ 40.00)	**$ 29.95**
PIGGYBACK Bracket for camera, for 2080	(List: $ 50.00)	**$ 36.95**
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T-Adapter for camera, Mod. 62, for all	(List: $ 50.00)	**$ 36.95**
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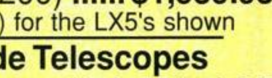

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PwrStr-C8 II ...... (List: $3,000) **........ $1,679.95**

FREE FREIGHT! (UPS Ground) for the PS-C8 II shown above

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Electric Focuser, for PS-C8 II	(List: $ 150.00)	**$ 99.95**
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T-Adapter for camera, for C8 Tubes	(List: $ 40.00)	**$ 29.95**
Off-Axis Photographic Guider System, complete, for C8 Tube ..	(List: $ 250.00)	**$174.95**
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STANDARD FEATURES & FACTORY-SPECIFIED EQUIP

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SP-C8 .... (List: $1,620) **.......... $ 949.95**
SP-C8 StrBrt ...... (List: $1,800) **.......... $1,099.95**

FREE FREIGHT! (UPS Ground) for the SP-C8's shown above

Accessories for SP-C8 Telescopes

8x50mm St-Thru/RtAngle Finder & Mounting Bracket	(List: $ 200.00)	$ 99.95
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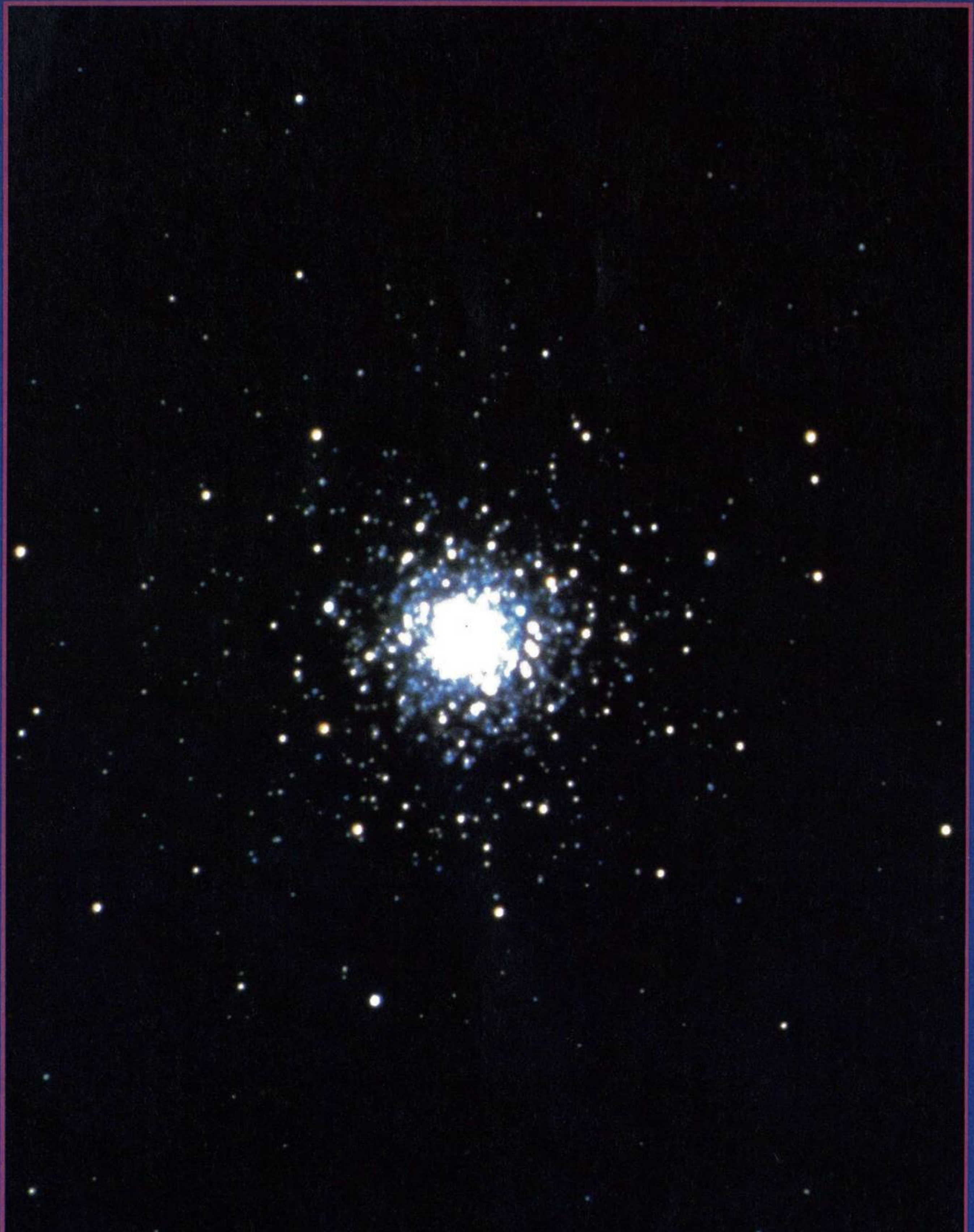
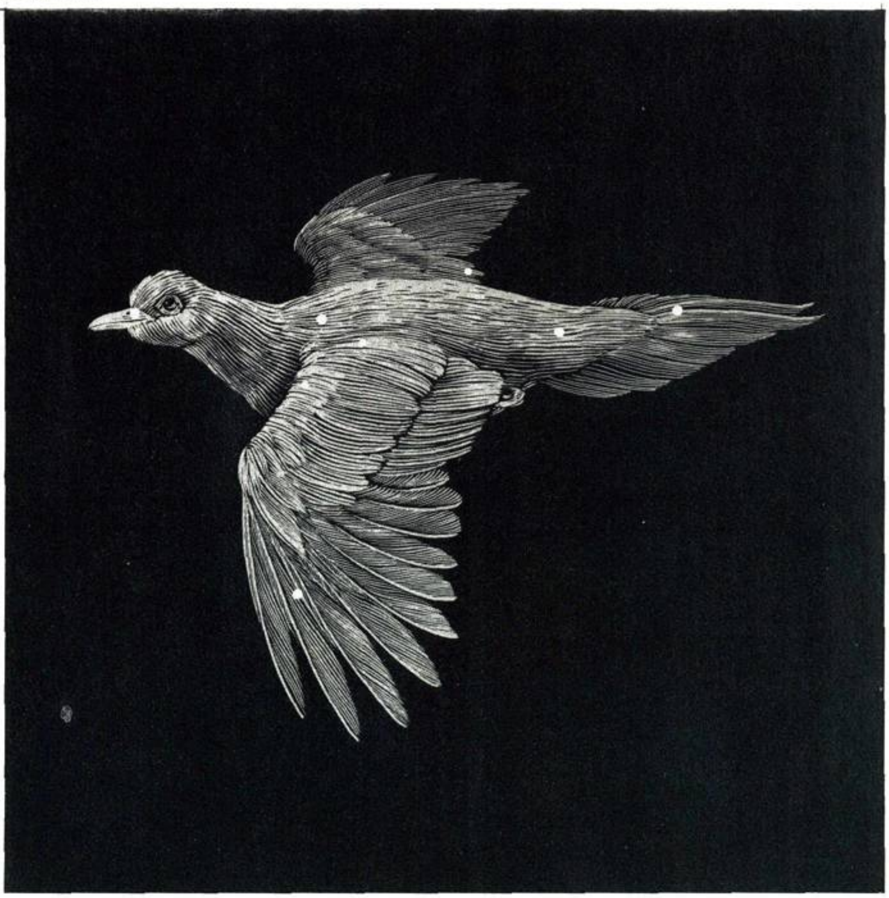


Glowing at magnitude 7.3 and spanning 11', globular cluster NGC-1851 is Columba's brightest and largest deep-sky object. Courtesy National Optical Astronomy Observatories.

Caelum
Cae
Caeli

Columba
Col
Columbae

Pictor
Pic
Pictoris


Keith Ward

Located between the bright forms of Canis Major and Carina to the east and the dim, winding figure of Eridanus to the west are the faint southern constellations Caelum, Columba, and Pictor. **Caelum** the Chisel is one of a group of faint constellations named by Nicolas Louis de Lacaille in the eighteenth century. It holds one faint galaxy. **Columba** the Dove is not difficult to recognize under a dark sky: its brightest stars shine at magnitude 3. This star group contains a bright globular star cluster, a handful of galaxies, and one unusual star. **Pictor** the Painter's Easel, another of Lacaille's creations, is a faint constellation holding a star that became a nova in 1925 and a couple of galaxies.

The brightest deep-sky objects of these three constellations are in Columba. **NGC-1851**, a magnitude 7.3 globular cluster, lies in an otherwise barren area in Columba's southwestern corner. Covering a full 11′ of sky, NGC-1851 is easily visible in binoculars as a small, misty clump of light. A 4-inch telescope shows this cluster as a pale disk spanning 5′ with a slight central condensation. Under a dark sky a 6-inch telescope just resolves the cluster's brightest stars, revealing its nature. Large backyard telescopes show speckles of faint stars strewn across an 8′-diameter soft, unresolved glow of light.

Three degrees northwest of NGC-1851 — halfway between the globular and the bright double star Gamma (γ) Columbae — lies a pair of galaxies easily accessible to small telescope users. Lying in a bright starfield, **NGC-1792** is an Sb-type spiral that glows at magnitude 10.2 and measures 4.2′ by 2.1′. Because it is relatively bright, NGC-1792 is rather easy to pick up in a small telescope. A 4-inch reflector shows the object as a pale smear of light some 2′ long. An 8-inch telescope shows the galaxy as a 3′ by 1′ elongated oval of light without much central condensation. The surface brightness of this galaxy rises slowly toward the center, but there is no sharply defined nucleus, which is typical of Sb-type spirals.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

One degree northeast of NGC-1792 — and visible in the same low-power field — is the 10th-magnitude barred spiral **NGC-1808**. At low power or on nights of average transparency NGC-1808 appears very much like its neighbor. However, view NGC-1808 on a dark night — especially at high power — and you'll see some subtle differences. NGC-1808 appears longer and broader than NGC-1792 and has a bright, condensed, ball-like nucleus. Large telescopes at high power may show slight mottling over NGC-1808's spiral arms, which is indicative of dust lanes and patches.

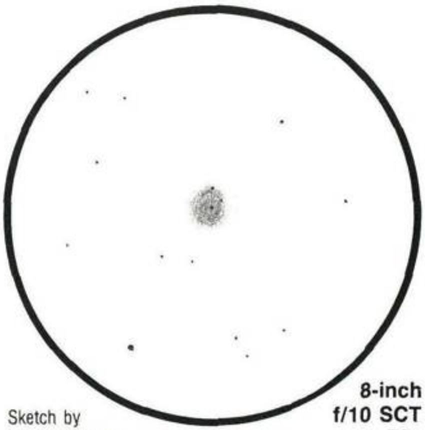
Seven degrees north of NGC-1792 lies a group of faint galaxies visible in small telescopes. **NGC-1800** is a tiny elliptical galaxy located 4° north and slightly east of Gamma Columbae. (A helpful check on the location is provided by a 6th-magnitude star lying 1° to the west.) This little galaxy is visible as a pale spot of light equaling a magnitude 12.6 star in brightness. NGC-1800 measures 1.6′ by 0.9′ but appears nearly round in backyard telescopes. Even large backyard instruments — 12 to 16 inches in aperture — don't show any detail in this object but only a slight concentration toward the center.

Equally faint is the tiny face-on spiral **UGC A103**, found 1° northeast of NGC-1800. UGC A103, the 103rd object in the addendum of the *Uppsala General Catalogue* of galaxies, glows softly at blue magnitude 13.1 and measures 2.5′ by 2.4′. This galaxy appears similar to NGC-1800, showing no detail except for a slight central condensation. About 1.5° southeast of UGC A103 is another galaxy, **UGC A106**. This faint irregular galaxy is very different from UGC A103. UGC A106 has a magnitude of 12.6 and dimensions of 3.4′ by 2.5′. The galaxy has a very low surface brightness, so its small — almost stellar — nuclear bulge is visible with a faint, uniformly illuminated halo of light surrounding it.

Located 2.5° northeast of UGC A106, **NGC-1879** is a faint face-on barred spiral. With a blue magnitude of 13.2 and diameter of 2′, NGC-1879 appears as a pale round patch of light in medium-size telescopes. Large telescopes show a slight central condensation. A faint star lies on the galaxy's northeastern side, and a 9th-magnitude star is located some 10′ to the northwest.

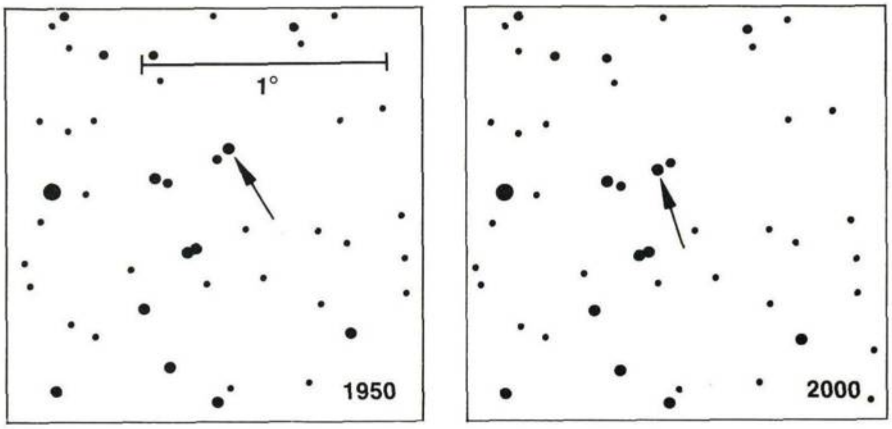
Appearing as a small oval patch with a bright, condensed center, the galaxy **NGC-2090** lies in central Columba, midway and slightly north of a line drawn between the 3rd-magnitude stars Alpha (α) and Beta (β) Columbae. This galaxy is a

NGC-1851



Sketch by
David J. Eicher

8-inch
f/10 SCT
50x



Kapteyn's Star, named for the astronomer who discovered it, is one of the fastest-moving stars in the sky. The star's proper motion will have carried it 7.3′ relative to field stars between 1950 and 2000.

blue magnitude 11.8 Sc-type spiral measuring 4.5′ by 2.3′.

On the eastern side of Columba, 2.5° northwest of the 4th-magnitude star Kappa (κ) Columbae, lies **NGC-2188**. NGC-2188 is fun to observe because it is bright enough to be visible in small scopes and has a thin, spindlelike appearance. This object is a barred spiral spanning 3.7′ by 1.1′ and glowing at magnitude 11.8. Some 2.5° north of the galaxy NGC-2090, forming a right triangle with Alpha and Beta Columbae, is the 5th-magnitude star **Mu** (μ) Columbae. Visually Mu Columbae appears to be a normal blue-white star, but photographs made of the Mu Columbae region over many years show an odd situation. The star is moving away from the Orion association — a large group of young stars in Orion — at a rate of 1′ every 2,400 years. The stars 53 Arietis and AE Aurigae also appear to be moving away from the Orion association in different directions. Tracing the paths of these three stars backward in time shows the stars met at the Orion association several million years ago. Astronomers don't know what threw these three stars outward from the Orion complex, but some speculate that such a force could have been supernova-related.

Across Columba's western border in the tall, narrow, dim constellation Caelum lies a lone galaxy. **NGC-1679** is a magnitude 13.5 galaxy that measures 1.2′ by 0.8′ and is thought to be an Sc-type spiral. To find this object, first find the 6th-magnitude star Zeta (ζ) Caeli and then move 2.5° southeast. NGC-1679 lies in a rich starfield but is easy to pick up in an 8-inch scope under a dark sky. The galaxy appears as a circular haze 1′ across with a clearly defined bright center.

Situated too far south for many Northern Hemisphere viewers, Pictor offers three treats for those who can observe it above the murk and glow of the horizon. Just 1° northeast of the 5th-magnitude star Iota (ι) Pictoris is the lenticular galaxy **NGC-1705**. Spanning 1.8′ by 1.4′ and glowing at magnitude 12.3, this object appears as a dim oval of light in small scopes.

Kapteyn's Star, named for the Dutch astronomer Jacobus C. Kapteyn, is the second "fastest" star in the sky. Kapteyn's Star has the highest proper motion, or movement relative to other stars, of any star except Barnard's Star in Ophiuchus. This star is a red dwarf with a magnitude of 8.8, located 8.5° northwest of Beta Pictoris. Its motion across the sky carries it 8.7″ per year, or one degree every 414 years. Kapteyn's Star is a mere 3.9 parsecs away, which in part accounts for its rapid motion; mostly, however, the star's proper motion is large because the star is moving through space at 280 kilometers per second. (By comparison, the Sun plods along at a modest 20 kilometers per second.) To find this star, use the accompanying chart.

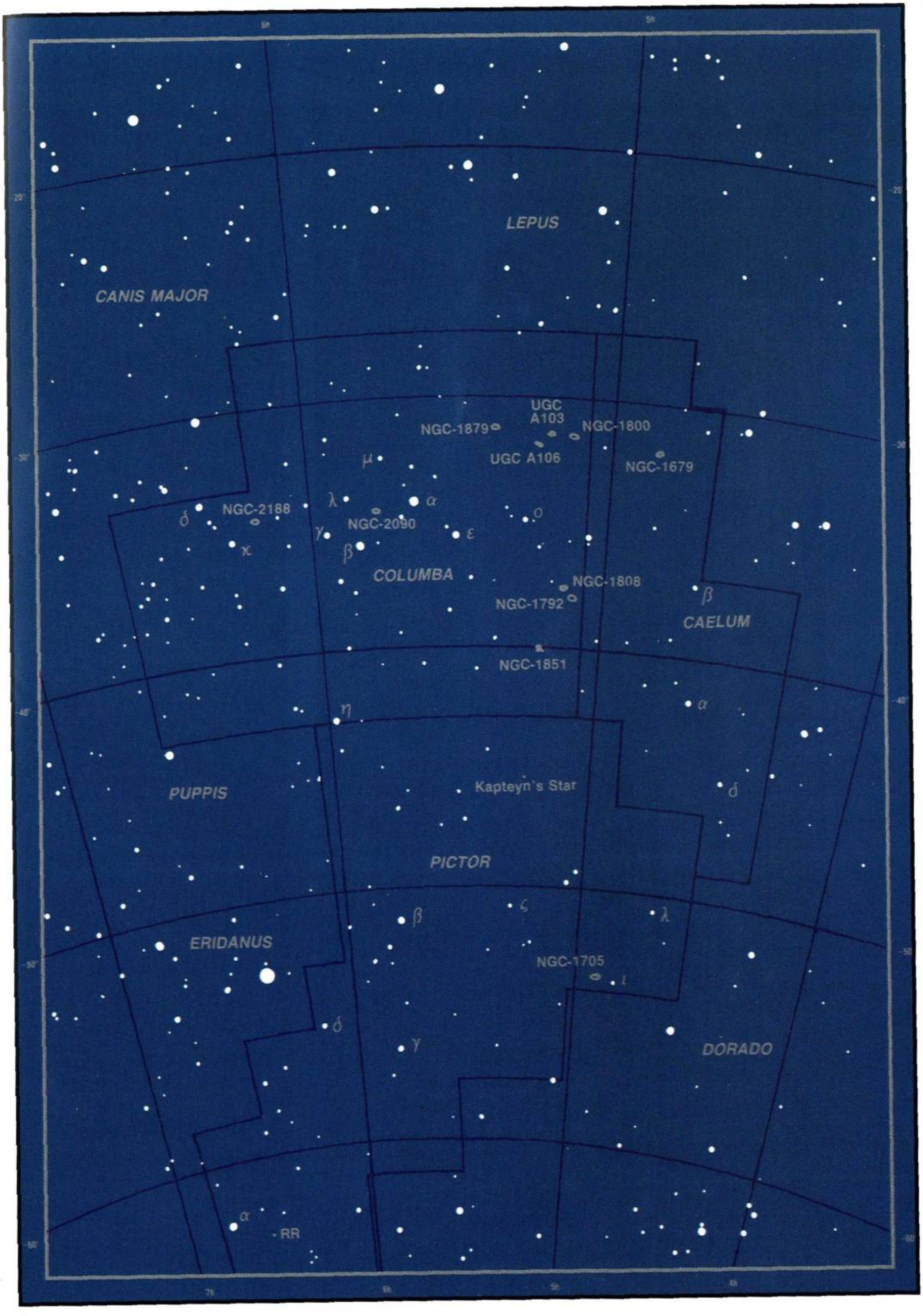
Way down at −63° declination, just 2° southwest of Alpha Pictoris and 6° northeast of the Large Magellanic Cloud, lies Pictor's other famous star. A century ago **RR Pictoris** shone at 12th-magnitude, but on May 25, 1925, the South African astronomer R. Watson noticed it gleaming at magnitude 2.3. RR Pictoris became a brilliant nova that spring and summer. By June 9, the star brightened to magnitude 1.2 and then faded to 4th magnitude by July 4. After fluctuating and attaining three maxima, the star faded rapidly and it now glows at its original 12th magnitude. For a time, however, RR Pictoris captured the eyes of all astronomers far enough south to see it.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-1679		§	4h 49.8m	−31°59′	13.5	1.2′x 0.8′	Sc:
NGC-1705		§L	4h 54.2m	−53°22′	12.3	1.8′x 1.4′	S0 pec.
NGC-1792		§	5h 05.2m	−37°59′	10.2	4.2′x 2.1′	Sb+
NGC-1800		§L	5h 06.4m	−31°57′	12.6	1.6′x 0.9′	E6
NGC-1808		§B	5h 07.7m	−37°31′	9.9	7.2′x 4.1′	S(B)a
UGC A103		§	5h 10.7m	−31°36′	13.1_B	2.5′x 2.4′	S+
Kapteyn's Star		★	5h 11.4m	−44°56′	8.8	—	
UGC A106		#	5h 12.0m	−32°58′	12.6	3.4′x 2.5′	Ir−
NGC-1851		●	5h 14.1m	−40°03′	7.3	11.0′	
NGC-1879		§B	5h 19.8m	−32°09′	13.2_B	2.2′x 1.9′	S(B)−
Mu (μ) Col		★	5h 45.9m	−32°18′	5.2	—	
NGC-2090		§	5h 47.0m	−34°14′	11.8_B	4.5′x 2.3′	Sc
NGC-2188		§B	6h 10.1m	−34°06′	11.8	3.7′x 1.1′	SBm
RR Pic		N	6h 35.6m	−62°39′	1.2↔12.4	—	

★	*Star*
N	*Nova*
●	*Globular Star Cluster*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*
§L	*Lenticular Galaxy*
#	*Irregular or Peculiar Galaxy*

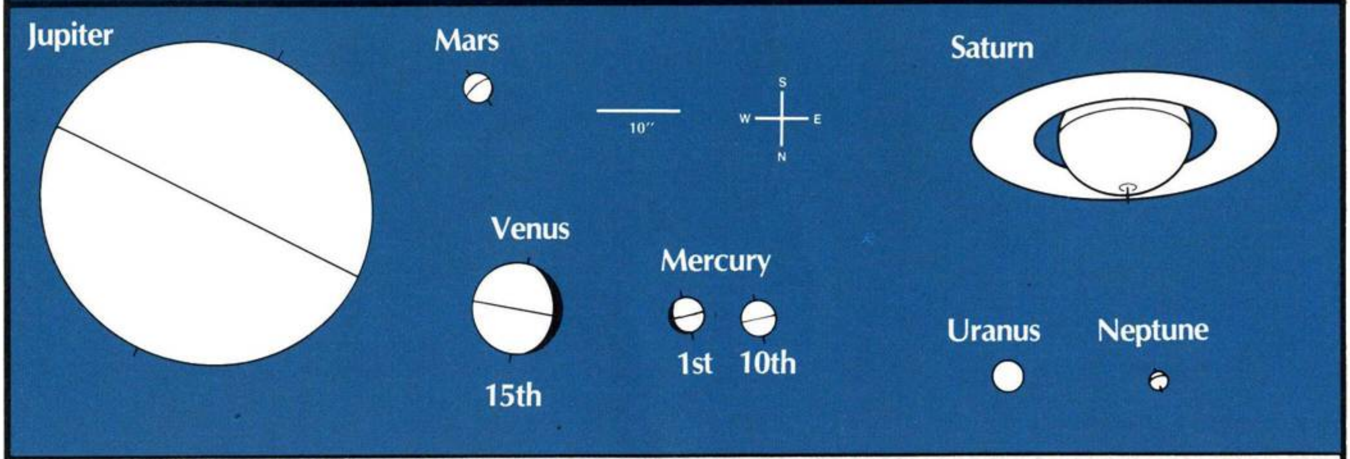
H = Hubble type for galaxies

Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.

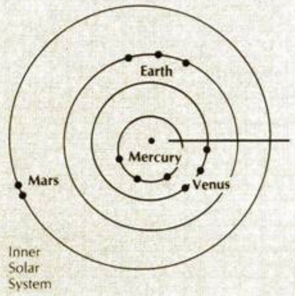

6h
5h
-20°
-20°
LEPUS
CANIS MAJOR
UGC
A103
NGC-1879
NGC-1800
UGC A106
NGC-1679
-30°
-30°
μ
λ
α
δ
NGC-2188
NGC-2090
o
γ
ε
ϰ
β
COLUMBA
NGC-1808
NGC-1792
β
CAELUM
NGC-1851
-40°
-40°
η
α
Kapteyn's Star
PUPPIS
δ
PICTOR
ζ
λ
β
ERIDANUS
NGC-1705
ι
-50°
-50°
δ
γ
DORADO
α
RR
-60°
-60°
7h
6h
5h
4h

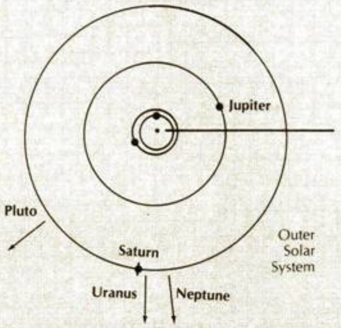
Planetary Data

December 1987


Jupiter
Mars
10″
S
W
E
N
Saturn
Venus
15th
Mercury
1st
10th
Uranus
Neptune

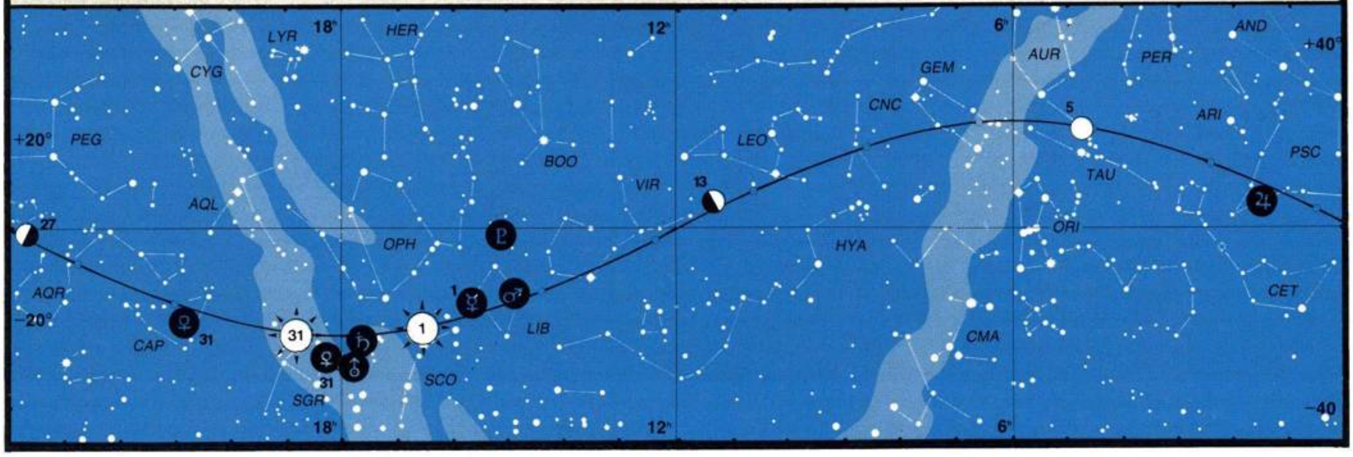
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.5′	—	0.986	—	—	248°15.0′	16h 26.7m	−21°42.7′
		15	−26.8	32.6′	—	0.984	—	—	262°27.8′	17h 27.0m	−23°14.3′
		31	−26.8	32.6′	—	0.983	—	—	278°45.7′	18h 38.8m	−23°08.6′
Mercury	☿	1	−0.7	5.0″	94%	1.335	0.426	206°42.1′	236°12.6′	15h 36.3m	−18°30.2′
		15	−0.9	4.7″	99%	1.439	0.465	248°00.4′	258°00.5′	17h 07.5m	−23°40.1′
		31	−1.0	4.8″	99%	1.416	0.445	293°15.0′	283°24.6′	18h 59.1m	−24°45.0′
Venus	♀	1	−3.9	11.2″	91%	1.483	0.728	309°11.1′	273°48.7′	18h 16.7m	−24°42.8′
		15	−3.9	11.8″	88%	1.419	0.728	331°20.6′	291°10.5′	19h 32.7m	−23°26.2′
		31	−4.0	12.5″	85%	1.339	0.727	356°44.1′	310°57.2′	20h 55.7m	−19°13.9′
Mars	♂	10	1.7	4.1″	97%	2.295	1.621	198°57.9′	220°34.4′	14h 33.4m	−14°21.8′
		20	1.6	4.2″	96%	2.227	1.612	203°36.1′	227°09.7′	14h 59.4m	−16°23.9′
Jupiter	♃	15	−2.6	44.4″	99%	4.431	4.960	29°55.5′	19°58.5′	1h 15.7m	6°31.2′
Saturn	♄	15	0.4	15.0″	100%	1.023	10.039	263°34.3′	263°38.5′	17h 32.5m	−22°09.6′
Uranus	♅	15	5.8	3.5″	100%	20.228	19.246	266°51.4′	266°49.7′	17h 46.1m	−23°34.1′
Neptune	♆	15	8.0	2.2″	100%	31.181	30.230	277°36.7′	277°21.1′	18h 31.6m	−22°16.9′
Pluto	♇	15	13.8	0.1″	100%	30.381	29.674	220°12.6′	221°36.5′	14h 56.2m	−0°17.8′

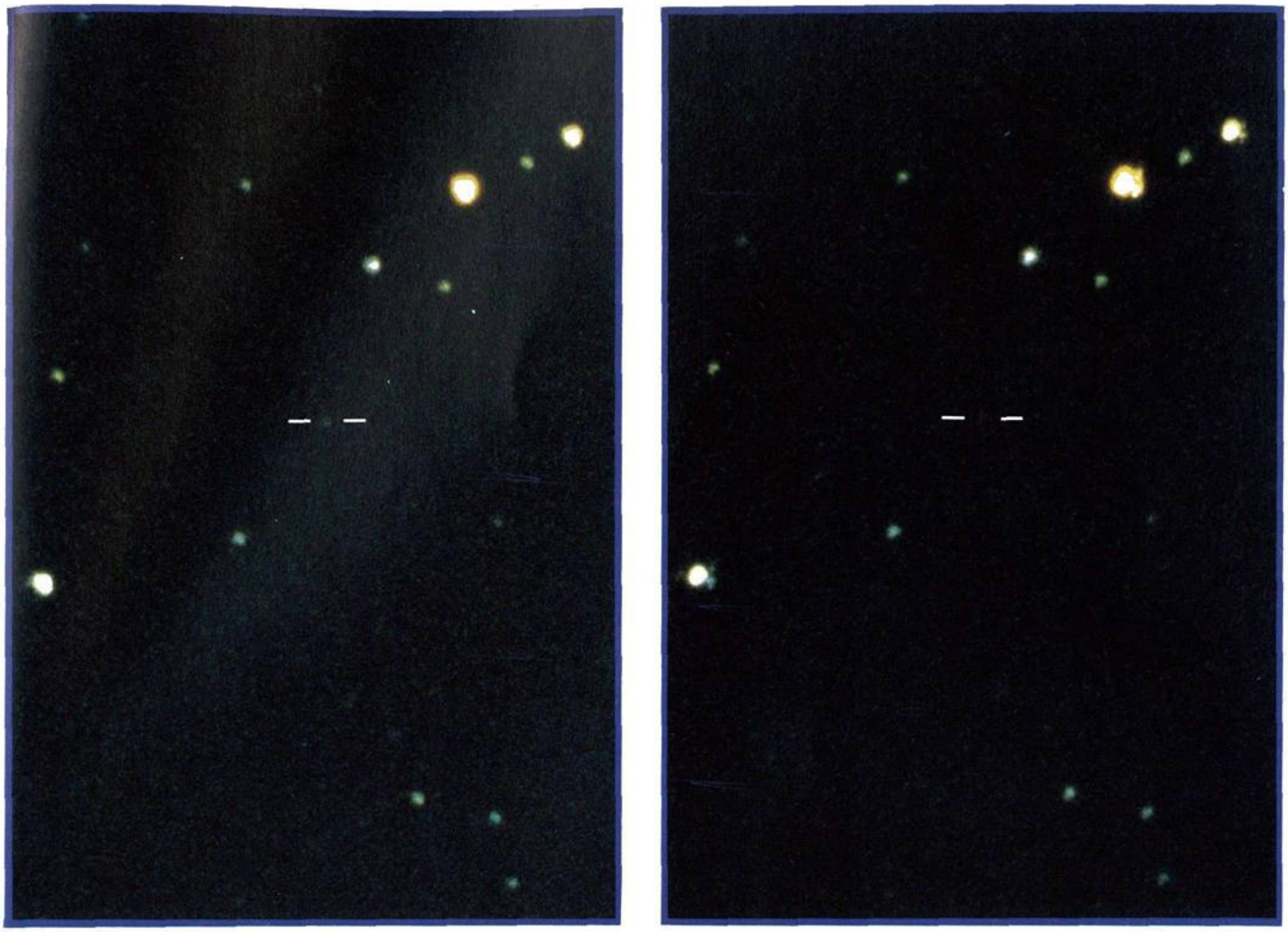

Earth
Mercury
Mars
Venus
Inner Solar System


Jupiter
Pluto
Saturn
Uranus
Neptune
Outer Solar System

Moon Data

Full Moon	Dec. 5 at 8h01m
Last Quarter	Dec. 13 at 11h41m
New Moon	Dec. 20 at 18h25m
First Quarter	Dec. 27 at 10h01m
Full Moon	Jan. 4 at 1h40m
Last Quarter	Jan. 12 at 7h04m
Apogee: Dec. 10 at 14h09m	405,117 km
Perigee: Dec. 22 at 11h12m	361,259 km


LYR
18h
HER
12h
6h
AUR
AND
+40°
CYG
GEM
PER
CNC
5
ARI
+20°
PEG
LEO
BOO
PSC
TAU
VIR
13
27
AQL
ORI
OPH
HYA
AQR
CET
−20°
CAP
31
31
1
LIB
CMA
SCO
SGR
31
18h
12h
6h
−40



Pluto and its moon Charon have undergone a series of eclipses and transits over the past couple of years. (See "How to View This Summer's Pluto-Charon Transits," Gazer's Gazette, May 1987.) These photos show the dimming of Pluto's image that results from such an eclipse. The photo at left began at 6h23m UT on June 23, and shows Pluto (arrow) during mid-eclipse. Pluto is noticeably brighter in the right-hand photo taken at 8h29m UT on the 23rd, shortly after the eclipse ended. Photos by Jay P. Price, who used a 10-inch SCT at f/6.3, 3M 1000 film, and 15-minute exposures.

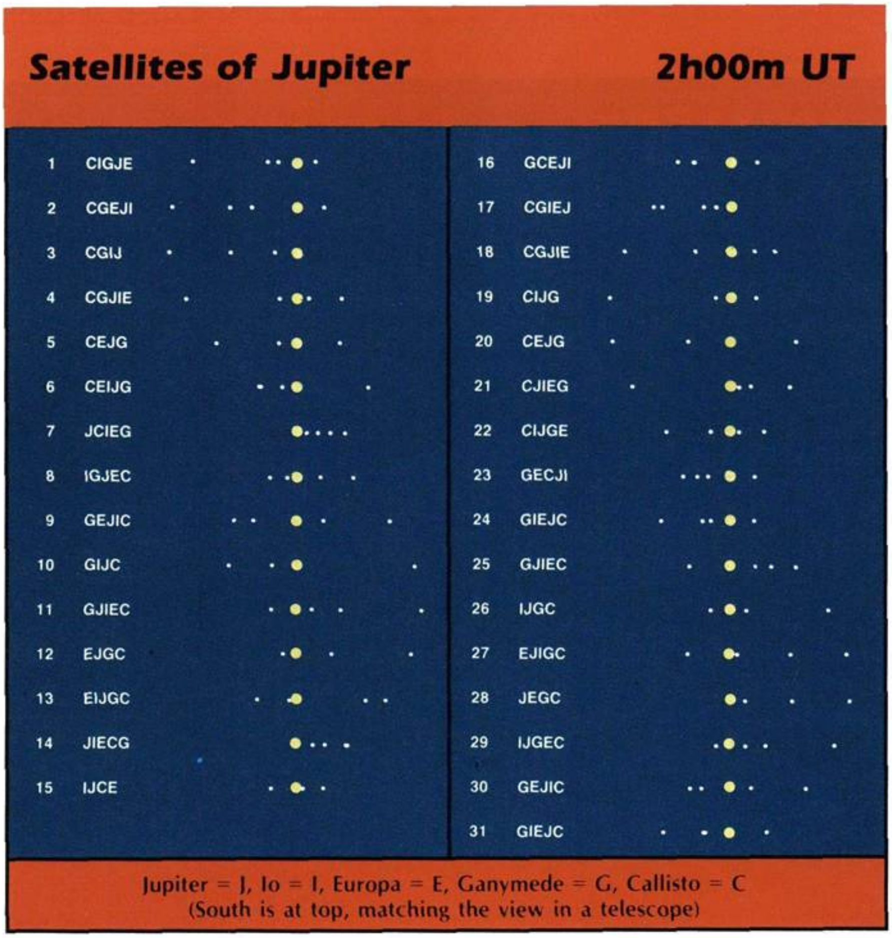
Mercury

In the morning sky during the first week of December Mercury finishes an apparition that began last month. Difficult to view on December 1, when it is 3° high, forty-five minutes before sunrise, Mercury is too low to view at all by about the 7th. If you have a clear morning sky during the first few days of the month, your scope will show an almost round Mercury about 5″ across that wavers in the eyepiece because of poor seeing near the horizon.

After it vanishes, Mercury crawls toward superior conjunction on December 23. The planet isn't visible again until well into January.

Venus

In December Venus becomes more prominent in the evening sky as it starts climbing directly upward from the hori-

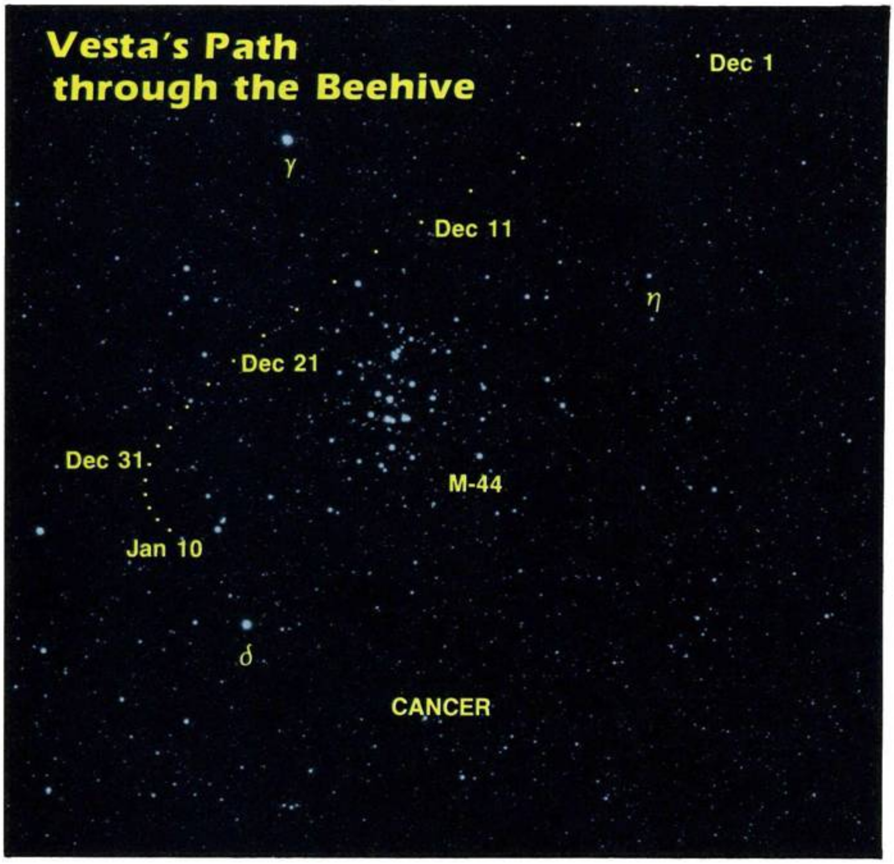


Satellites of Jupiter 2h00m UT

1	CIGJE	16	GCEJI
2	CGEJI	17	CGIEJ
3	CGIJ	18	CGJIE
4	CGJIE	19	CIJG
5	CEJG	20	CEJG
6	CEIJG	21	CJIEG
7	JCIEG	22	CIJGE
8	IGJEC	23	GECJI
9	GEJIC	24	GIEJC
10	GIJC	25	GJIEC
11	GJIEC	26	IJGC
12	EJGC	27	EJIGC
13	EIJGC	28	JEGC
14	JIECG	29	IJGEC
15	IJCE	30	GEJIC
		31	GIEJC

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

On July 28, 1987, an extremely bright aurora looped and pranced over Thunder Bay, Ontario, creating a show that "beat Halley hands down," according to observer Robert Mazur. Mazur's three-photo composite of the aurora is this month's $100 "Best Astrophoto" award winner. Mazur used a 28mm f/2.5 lens, 100 ISO Fujicolor film, and 15-second exposures to record the event.



zon. (To see the planet, you may still have to seek a site with a fairly unobstructed vista toward the southwest.) A telescope with medium to high magnification will reveal a white disk about 12" across. Venus will appear clearly noncircular, especially if you observe it with twilight brightening the sky around the planet.

Moon

On the morning of December 4, the nearly Full Moon passes through the Pleiades cluster, occulting many of the cluster's members. The event will be visible across most of North America in the hours between midnight (for observers on the West Coast) and early predawn (East Coast). Use low-magnification, wide-field eyepieces to see the entire cluster and Moon and a high-power eyepiece to follow the individual disappearances.

Mars

Mars is a prominent object in the morning sky this month: it rises about four hours before the Sun and is conspicuous in the southeast as twilight begins.

In your telescope Mars will display a disk that measures 4.0" across (on the 1st) and grows slightly throughout the month. You will need good seeing, a moderate-aperture telescope (6 inches or larger), and high magnifications to discern more than a few dark markings.

Minor Planets

1 Ceres (magnitude 8.8) is moving eastward in eastern Sagittarius. Its positions:

1st: 19h 20m 41s, −27° 42.1′
10th: 19h 35m 29s, −27° 17.0′
20th: 19h 52m 09s, −26° 43.3′
30th: 20h 08m 59s, −26° 03.5′

Ceres sets in evening twilight and is difficult to locate.

2 Pallas is in conjunction with the Sun on December 29, and is out of view all month.

3 Juno (9.7) is moving eastward in Aquarius. Its positions:

1st: 22h 17m 28s, −12° 35.6′
10th: 22h 30m 11s, −11° 59.0′
20th: 22h 45m 34s, −11° 05.1′
30th: 23h 02m 04s, −9° 58.5′

Juno sets around 10:30 p.m. local time on the 15th.

4 Vesta (6.8) lies in Cancer and is passing near the Beehive Cluster, M-44 (see diagram on page 116). Its positions:

1st: 8h 46m 55s, 18° 49.4′
10th: 8h 47m 32s, 19° 13.1′
20th: 8h 45m 22s, 19° 53.1′
30th: 8h 40m 08s, 20° 46.6′

Vesta rises about 8:30 p.m. local time on the 15th.

20 Massalia (9.6) is moving retrograde in Taurus. At opposition on December 2, its positions are:

1st: 4h 34m 09s, 21° 04.2′
10th: 4h 24m 47s, 20° 41.4′
20th: 4h 15m 43s, 20° 17.8′
30th: 4h 09m 09s, 20° 00.5′

Massalia is visible all night.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Uranometria 2000.0*, for example, or *Sky Atlas 2000.0*) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is the asteroid. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Earth is drawing away from Jupiter, which makes Jupiter's apparent size dwindle, but at least by nightfall Jupiter has a relatively high elevation in the southeast. Because this places the planet where the seeing is good, Jupiter continues to offer a great deal to observers with telescopes.

Try to locate Jupiter before twilight has entirely faded, so you can see the planet's bright disk without dazzling your eye. Experienced observers often choose twilight views over others for this reason.

If Jupiter looks slightly lopsided this month, it's because we are not getting the straight-on view we get at opposition. We are to one side of the Jupiter-Sun line, and the planet's disk looks a little gibbous because a small part of Jupiter's nightside hemisphere is now in view. This effect will linger into January before disappearing as we round our orbit and begin to view Jupiter more straight on again.

Saturn

Saturn is in conjunction with the Sun on December 16 (15th EST) and is out of sight all month.

Uranus

Uranus is in conjunction with the Sun on December 19, and is out of view all month.

Neptune

Like Uranus and Saturn, Neptune is also in conjunction with the Sun this month (December 29) and is out of sight.

Pluto

Pluto-rise is still occurring too near to sunrise for the planet to be easily visible. Pluto passes 10′ south of the 6th-magnitude star 1 Serpentis in the last week of December, but because the planet is a slowly moving stellar dot at 14th magnitude, observing it requires a 10-inch or larger telescope. (1 Serpentis actually lies in Virgo; it is plotted near the 15h line on chart 14 of *Sky Atlas 2000.0*.)

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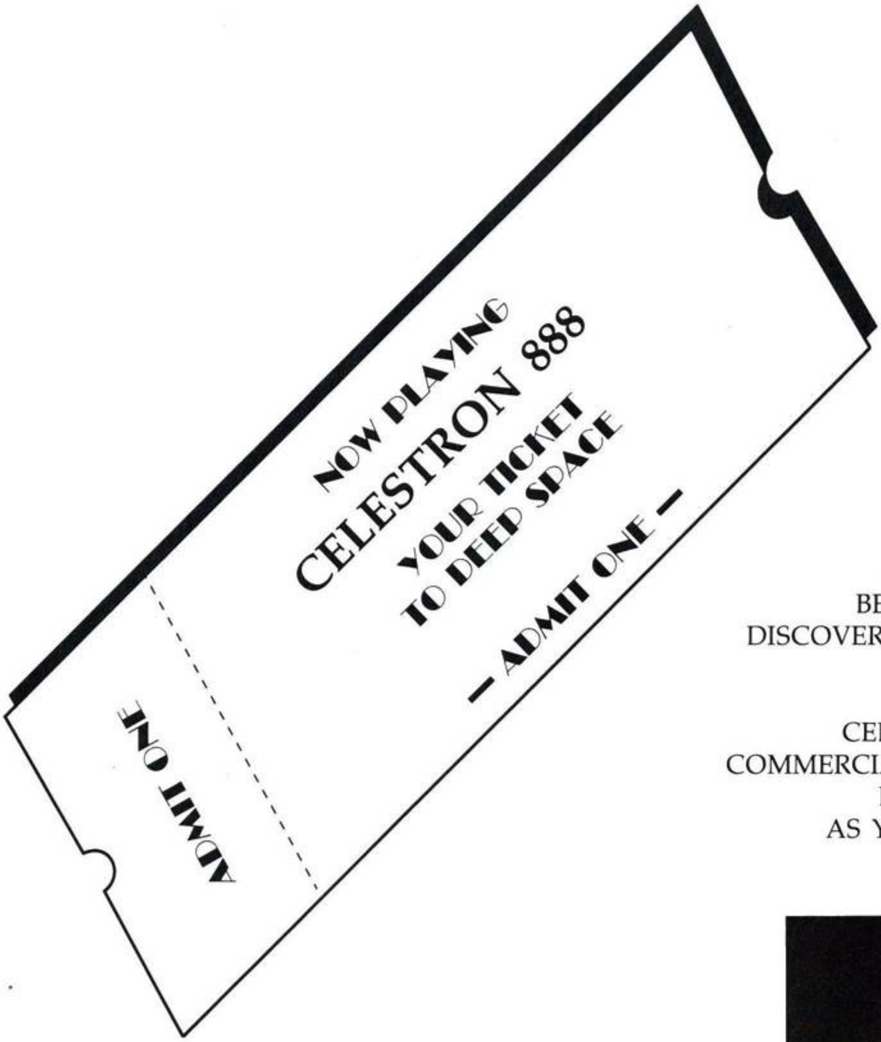

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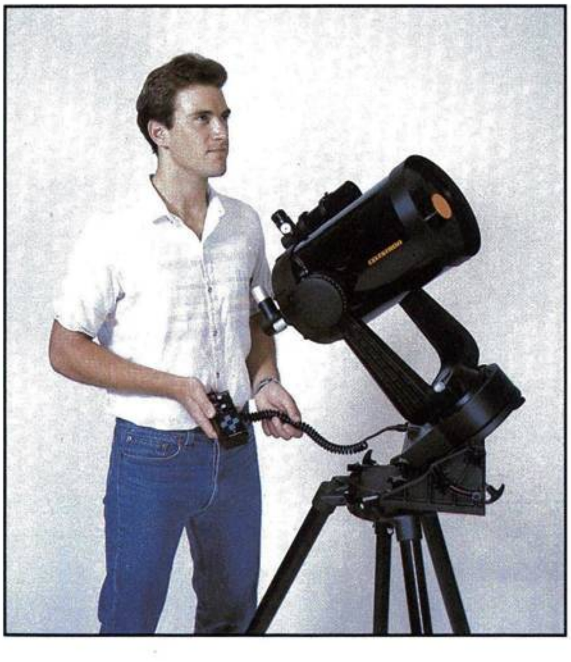

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